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(54) **OPERATIONAL MODES FOR A FIRE FIGHTING VEHICLE**

(71) Applicant: **Oshkosh Corporation**, Oshkosh, WI (US)

(72) Inventors: **Eric Linsmeier**, Larsen, WI (US); **David Archer**, Hortonville, WI (US); **Chad Smith**, Omro, WI (US); **Jon Morrow**, Neenah, WI (US)

(73) Assignee: **Oshkosh Corporation**, Oshkosh, WI (US)

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(52) **U.S. Cl.**

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(57) **ABSTRACT**

An electrified fire fighting vehicle includes a chassis, a cab coupled to the chassis, a body coupled to the chassis, a pump system, and a driveline. The driveline includes a front axle coupled to the chassis, a rear axle coupled to the chassis, an energy storage system, an engine coupled to the chassis, and an electromechanical device coupled to the chassis, the engine, and at least one of the front axle or the rear axle. The driveline is a dual drive driveline such that, during any and all modes of operation of the driveline, the electromechanical device is incapable of or prevented from charging the energy storage system at any time when driven by the engine.

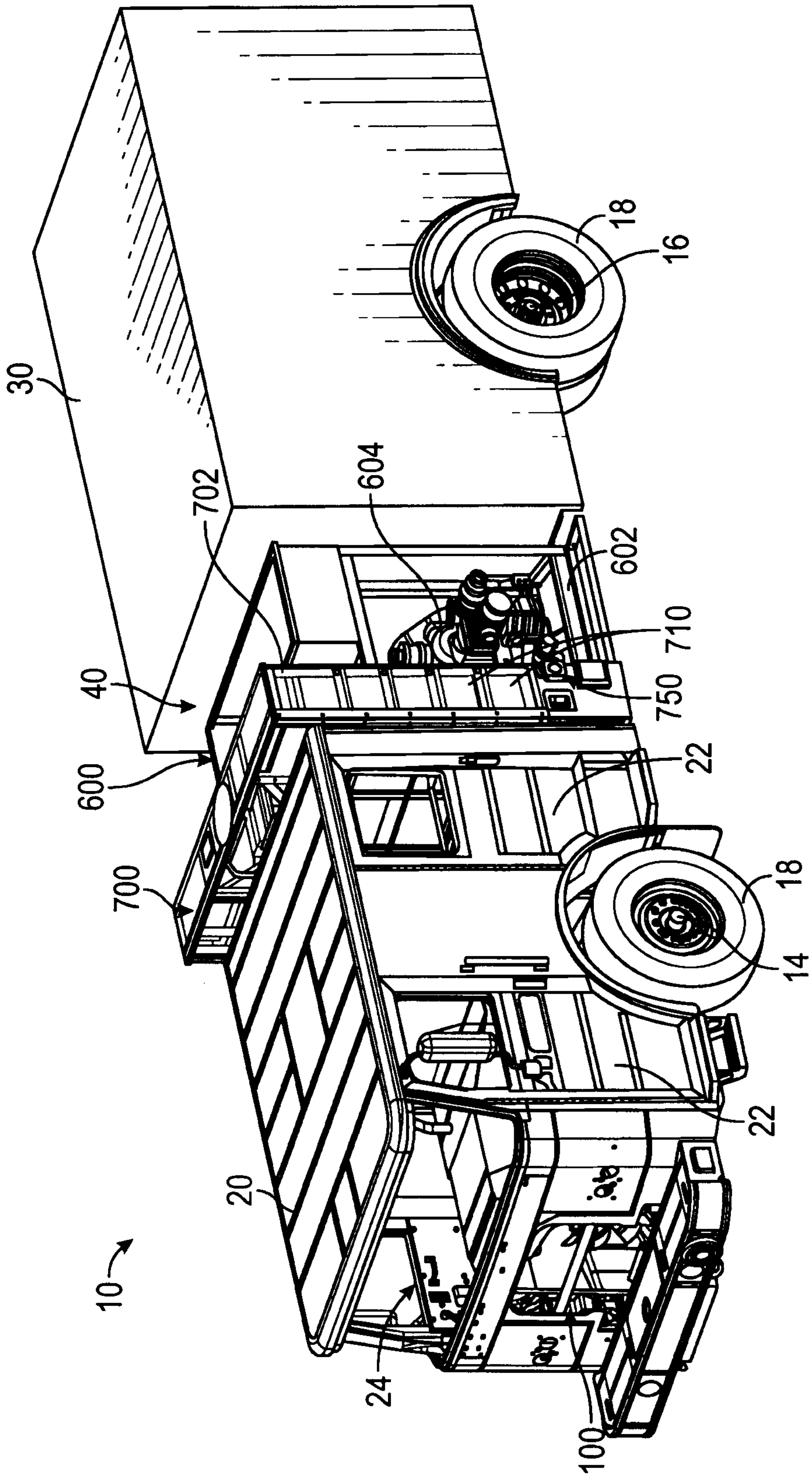


FIG. 1

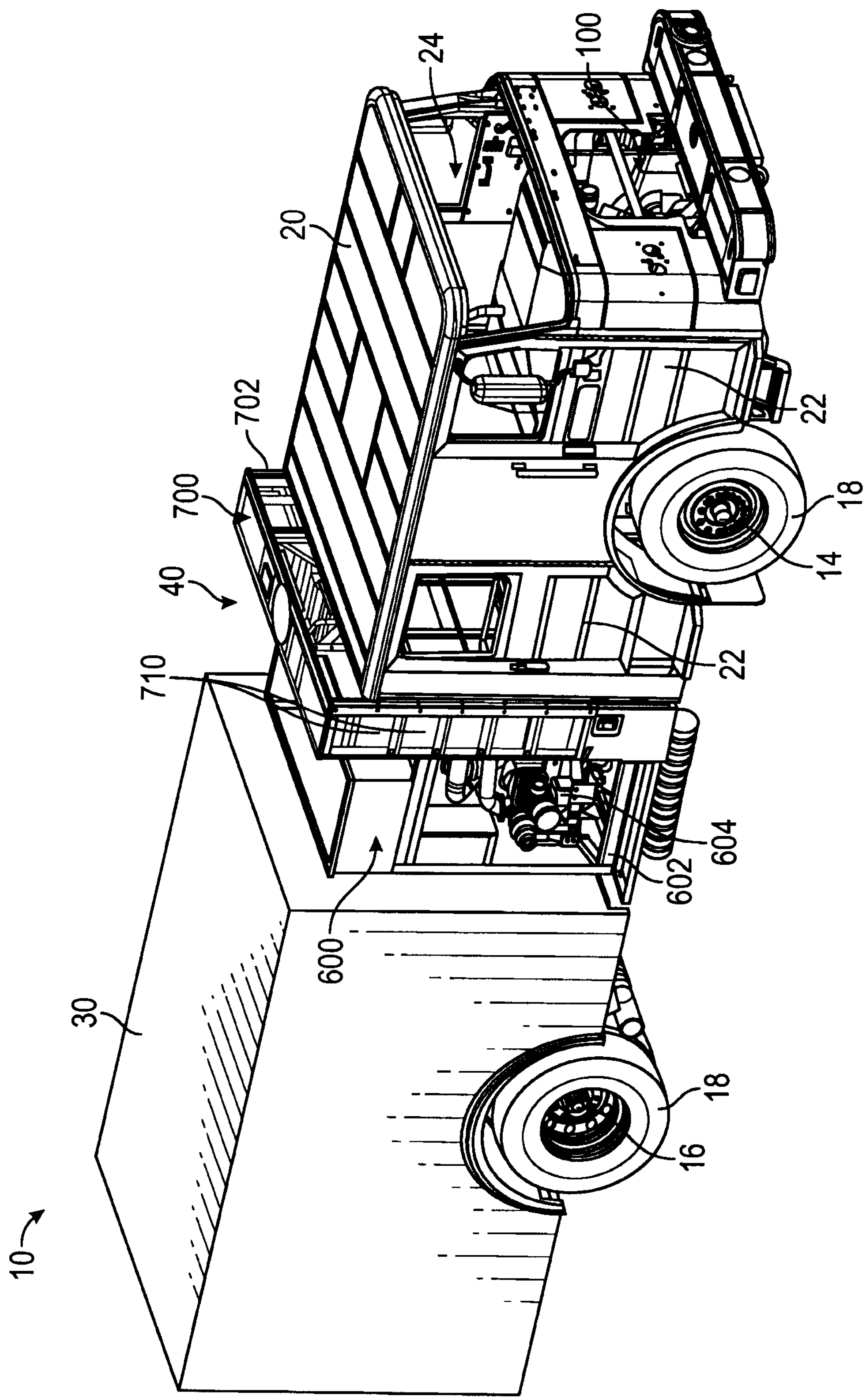


FIG. 2

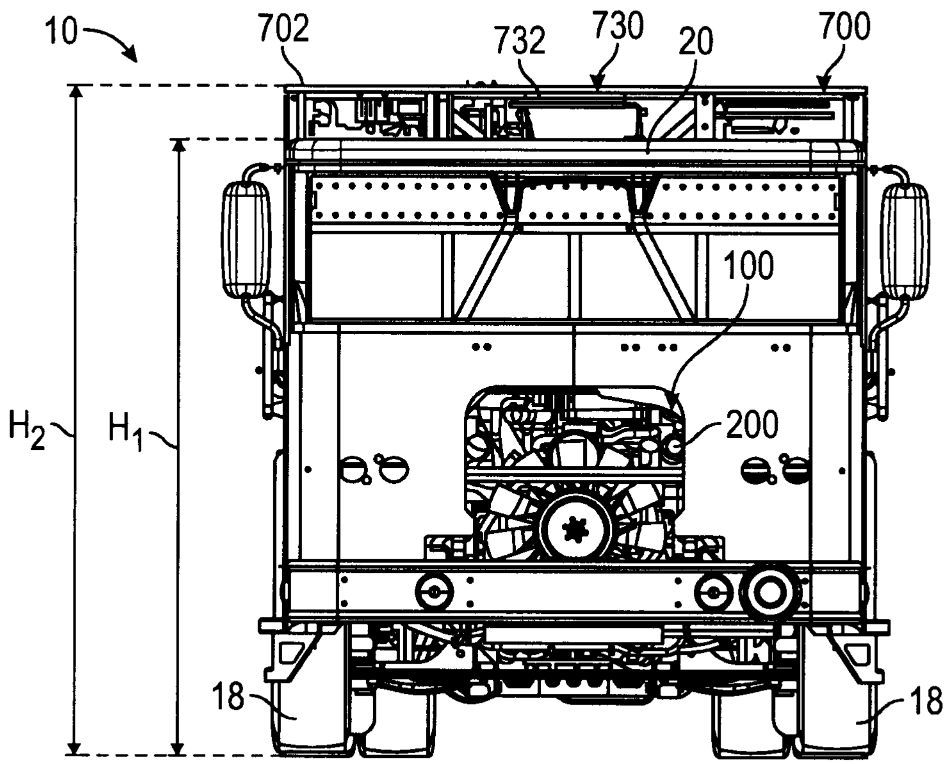
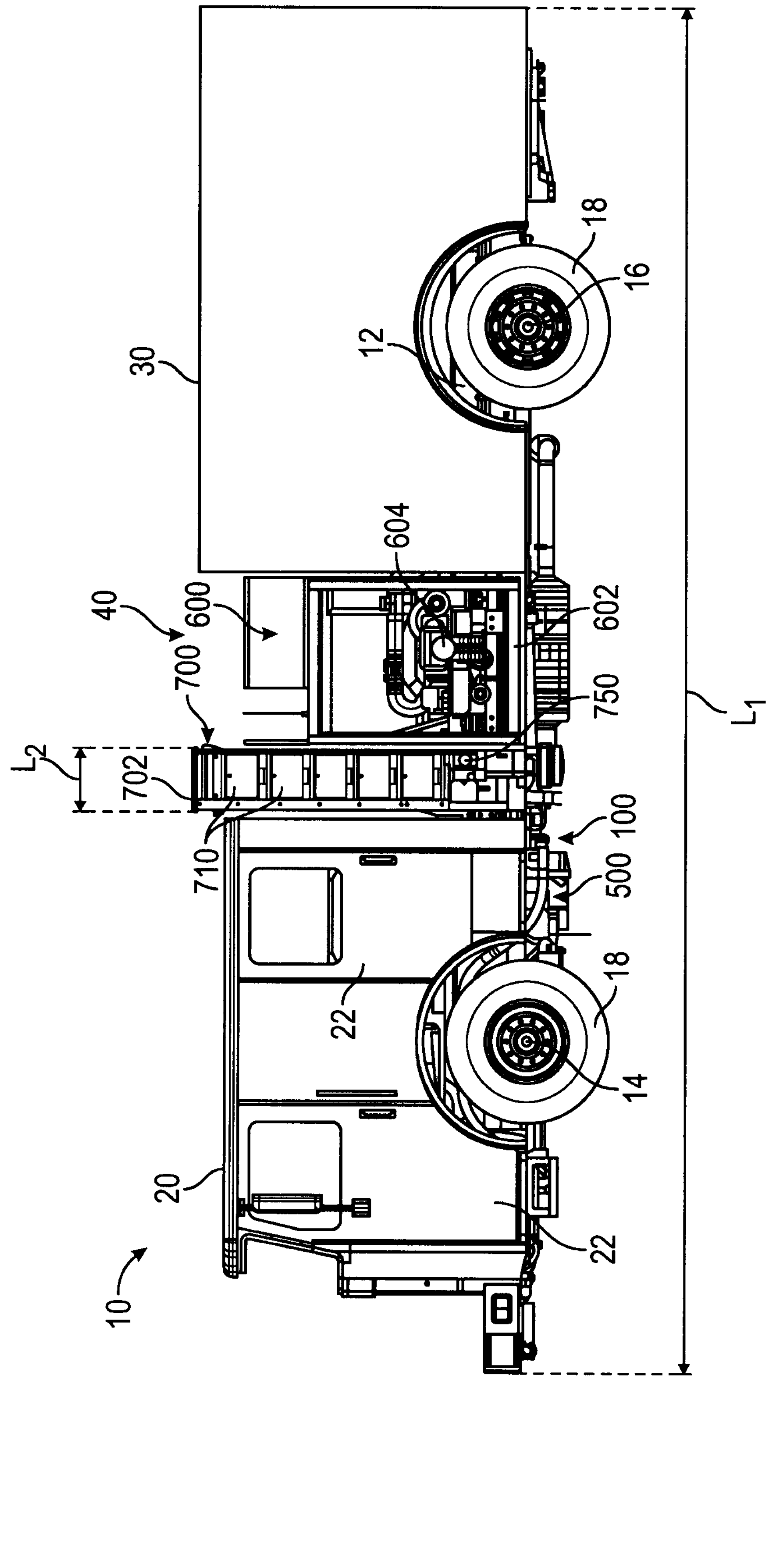


FIG. 3



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L1

FIG. 4

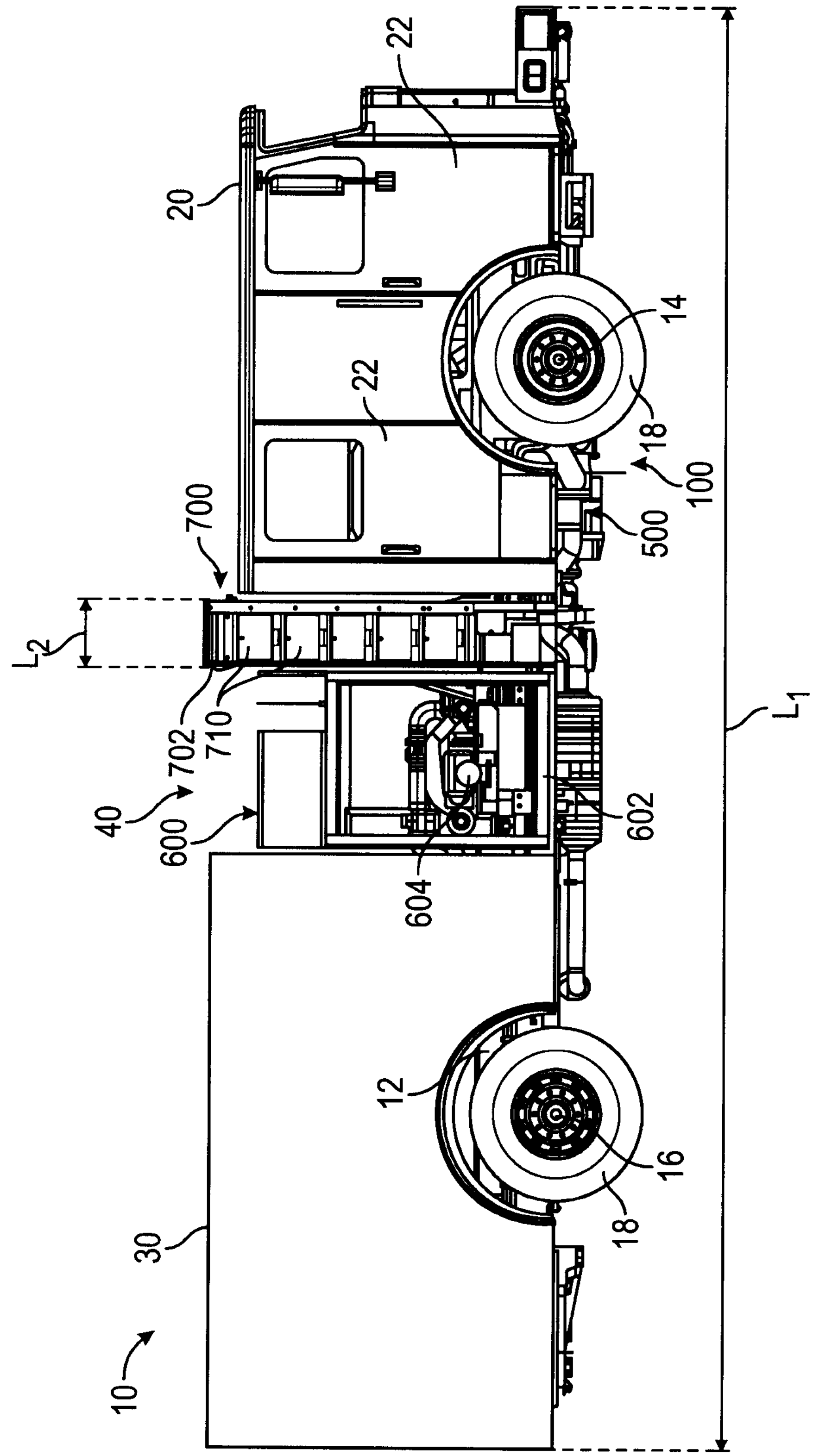
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FIG. 5

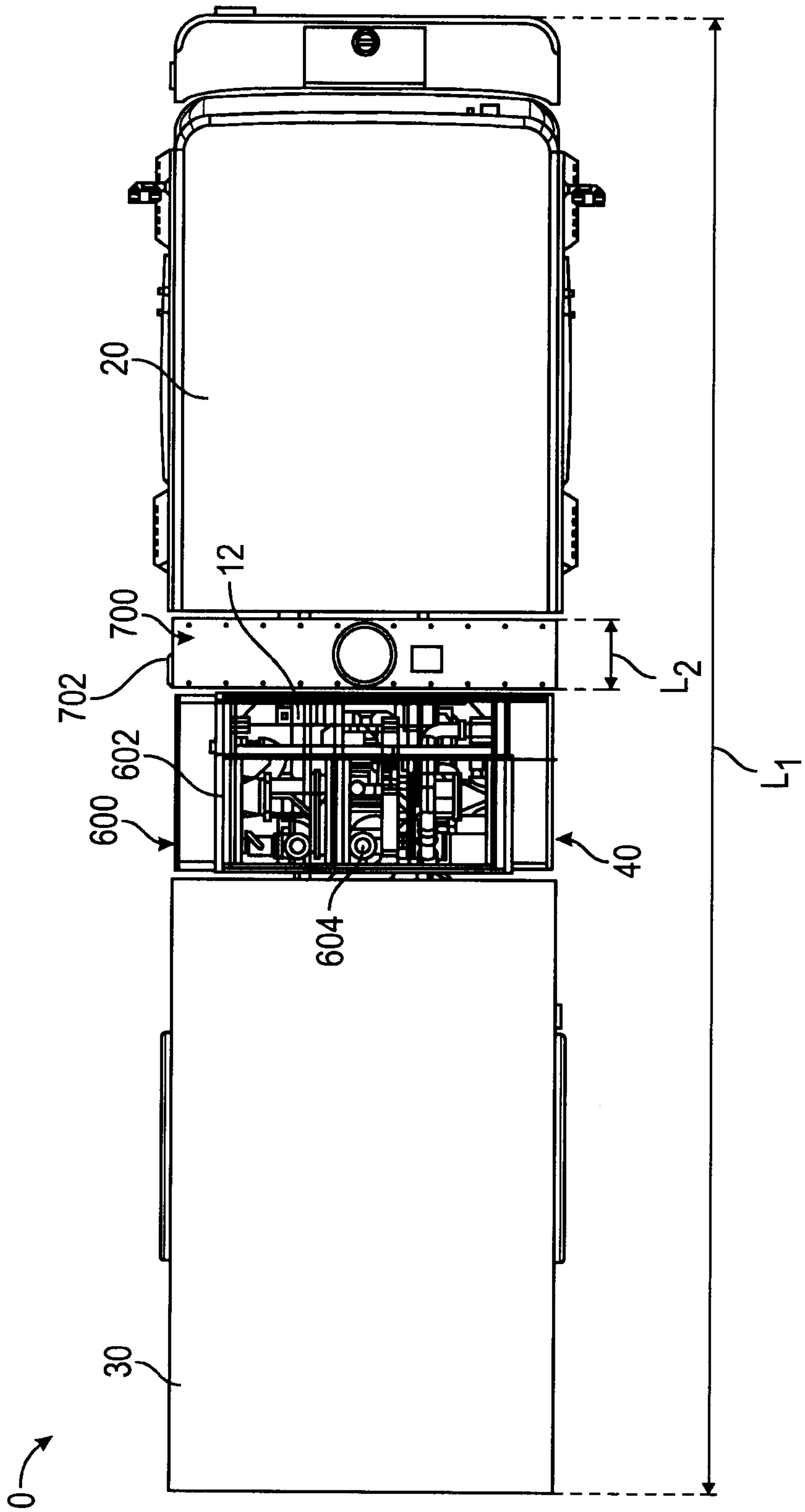
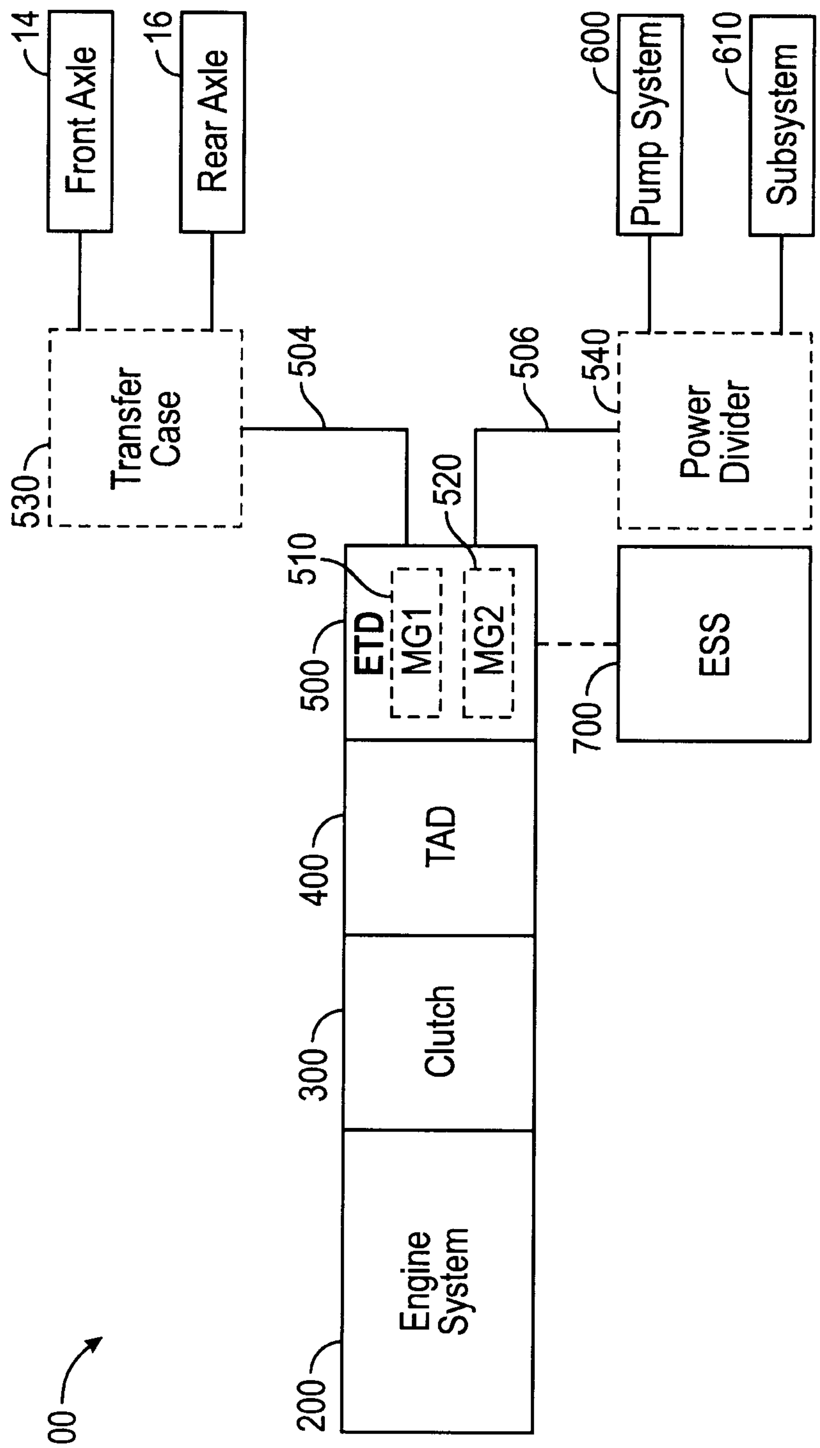


FIG. 6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Pump System
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Subsystem
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FIG. 7

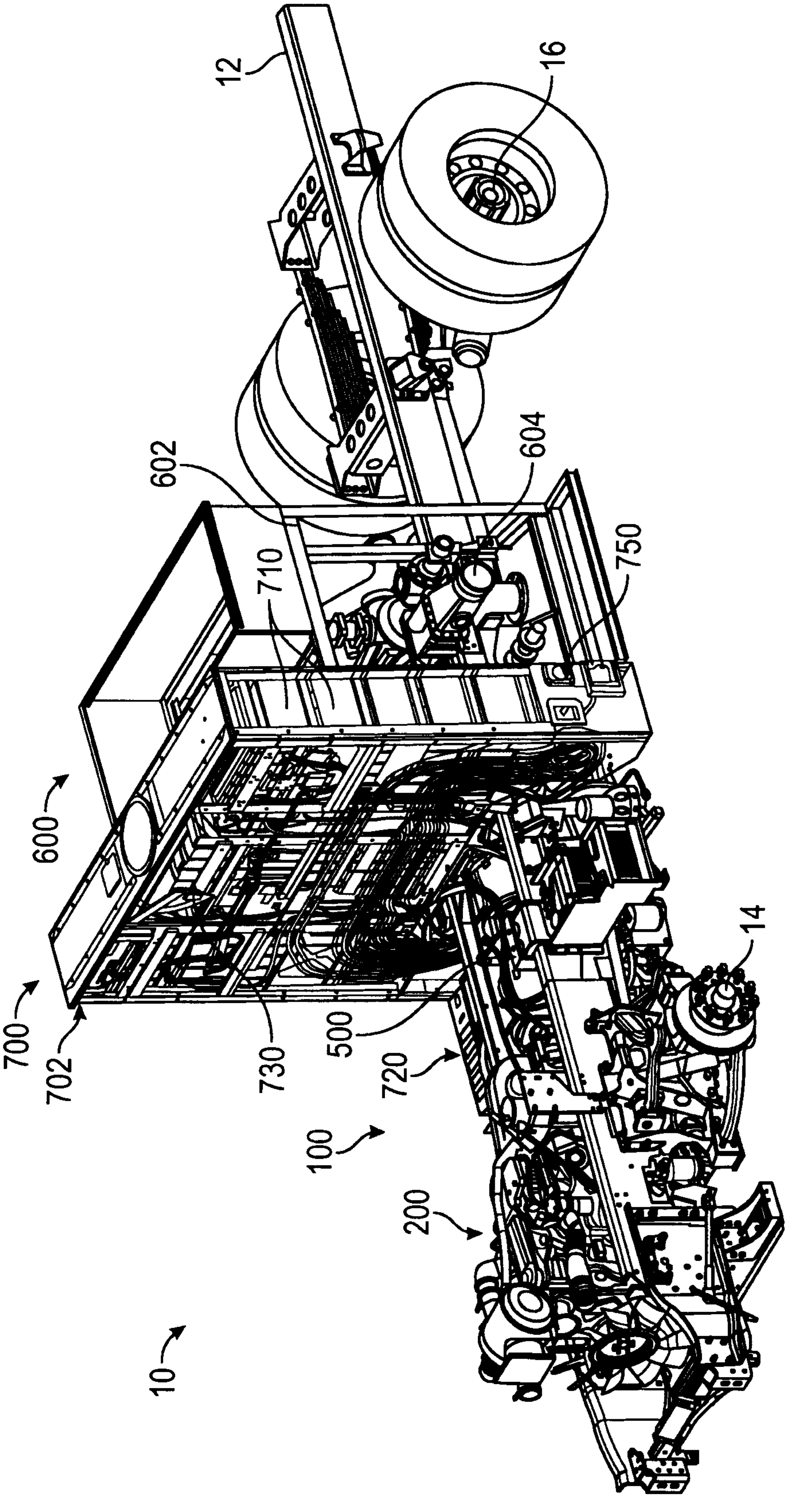

FIG. 8

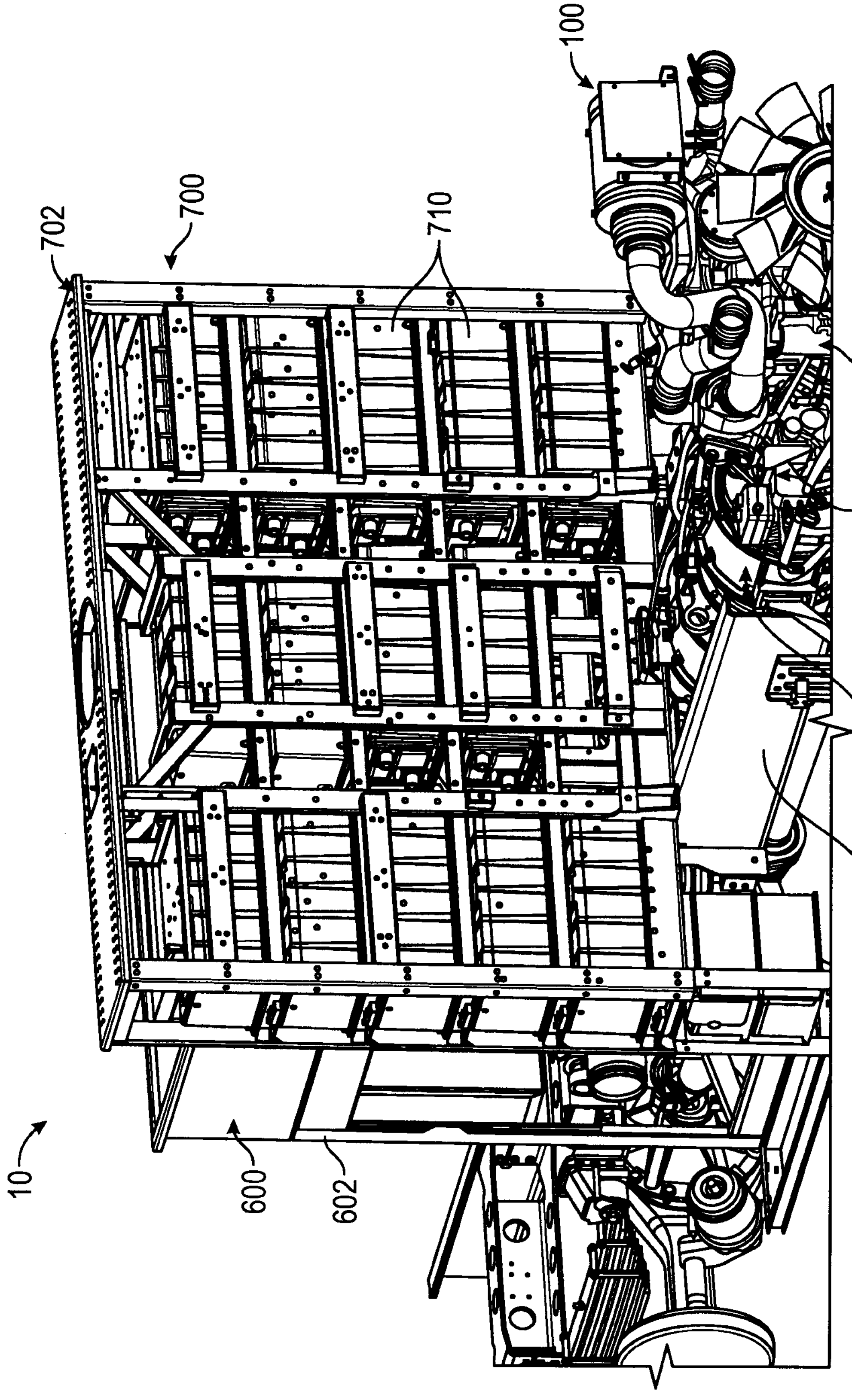

FIG. 9

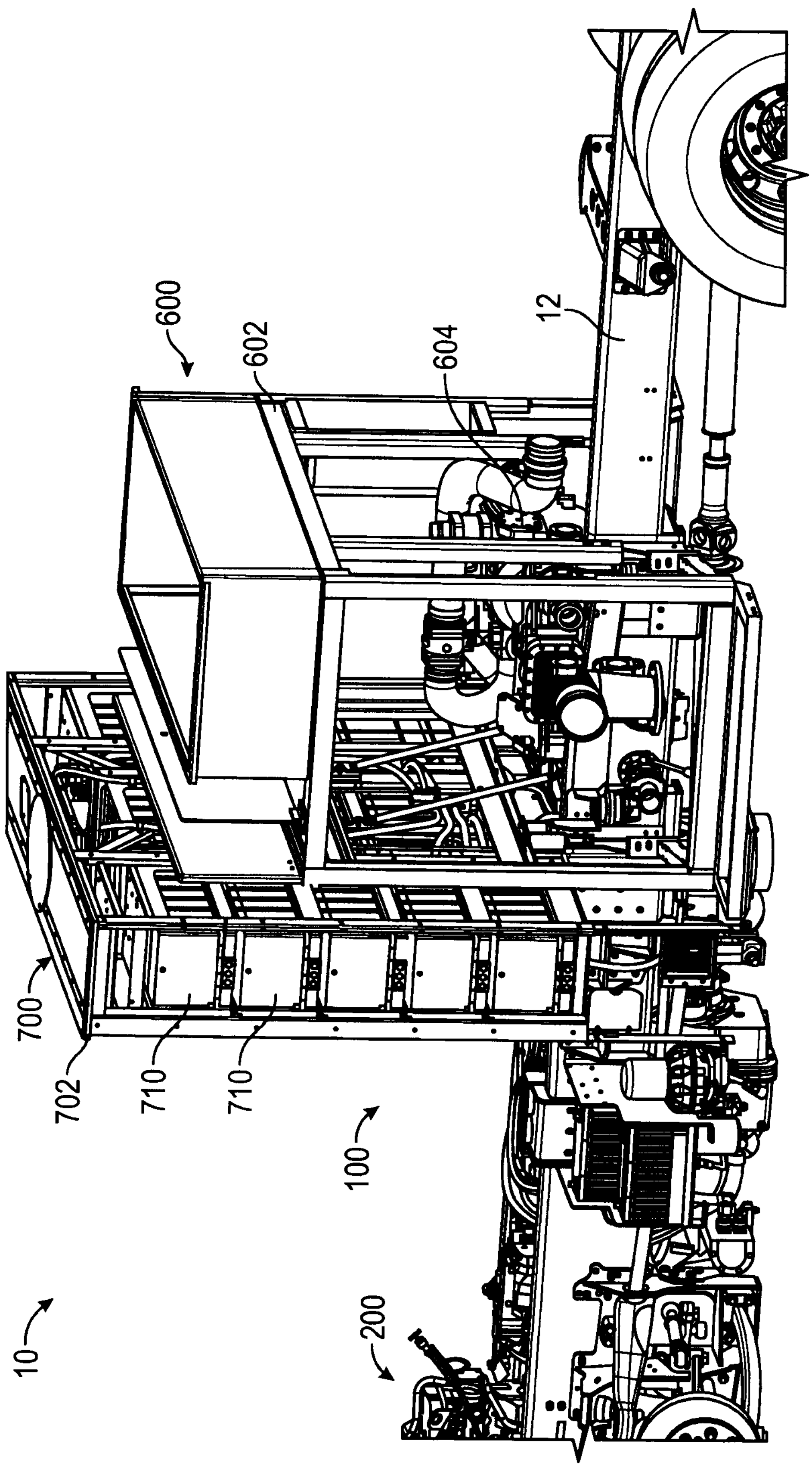

FIG. 10

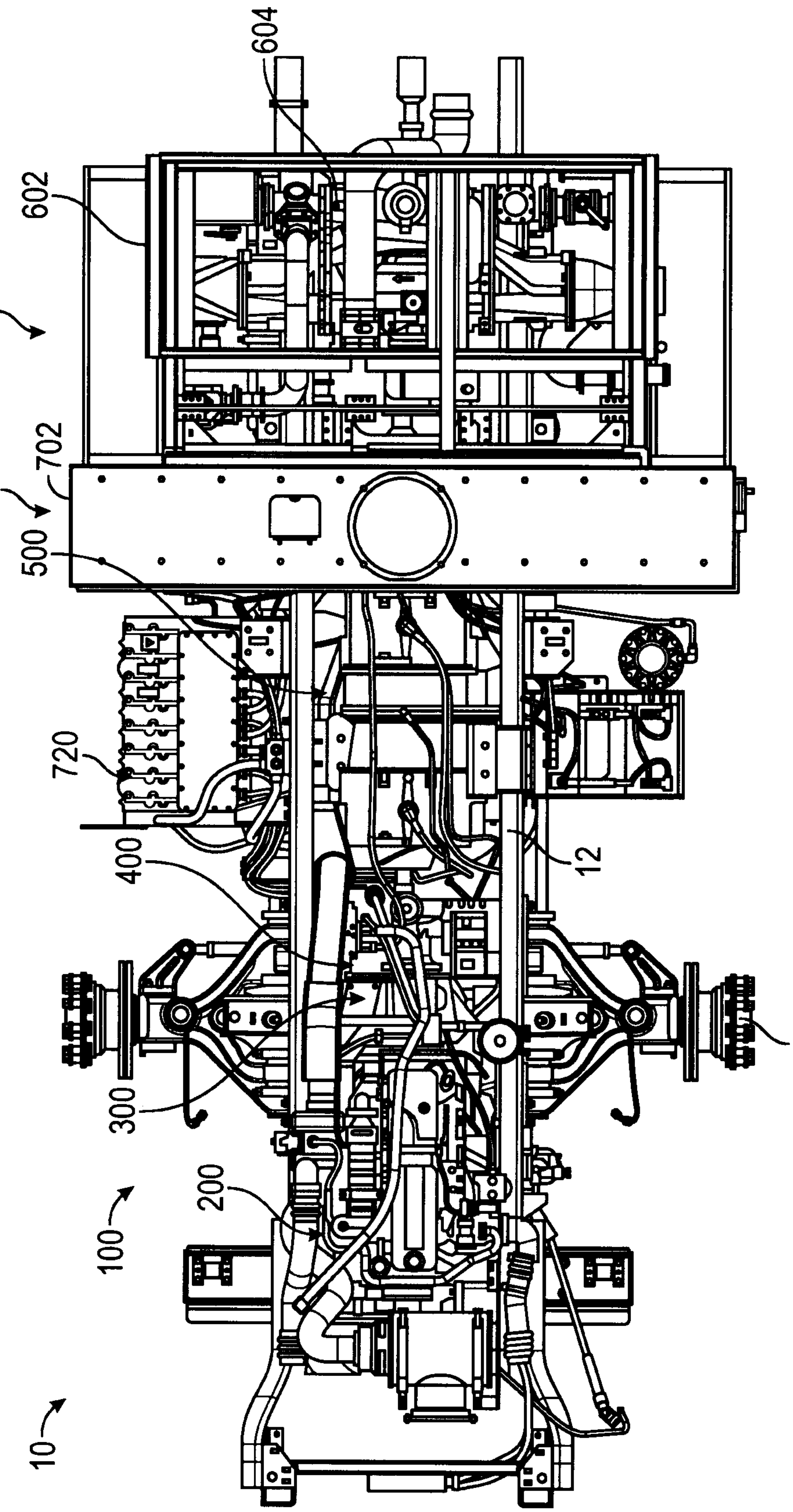

FIG. 11

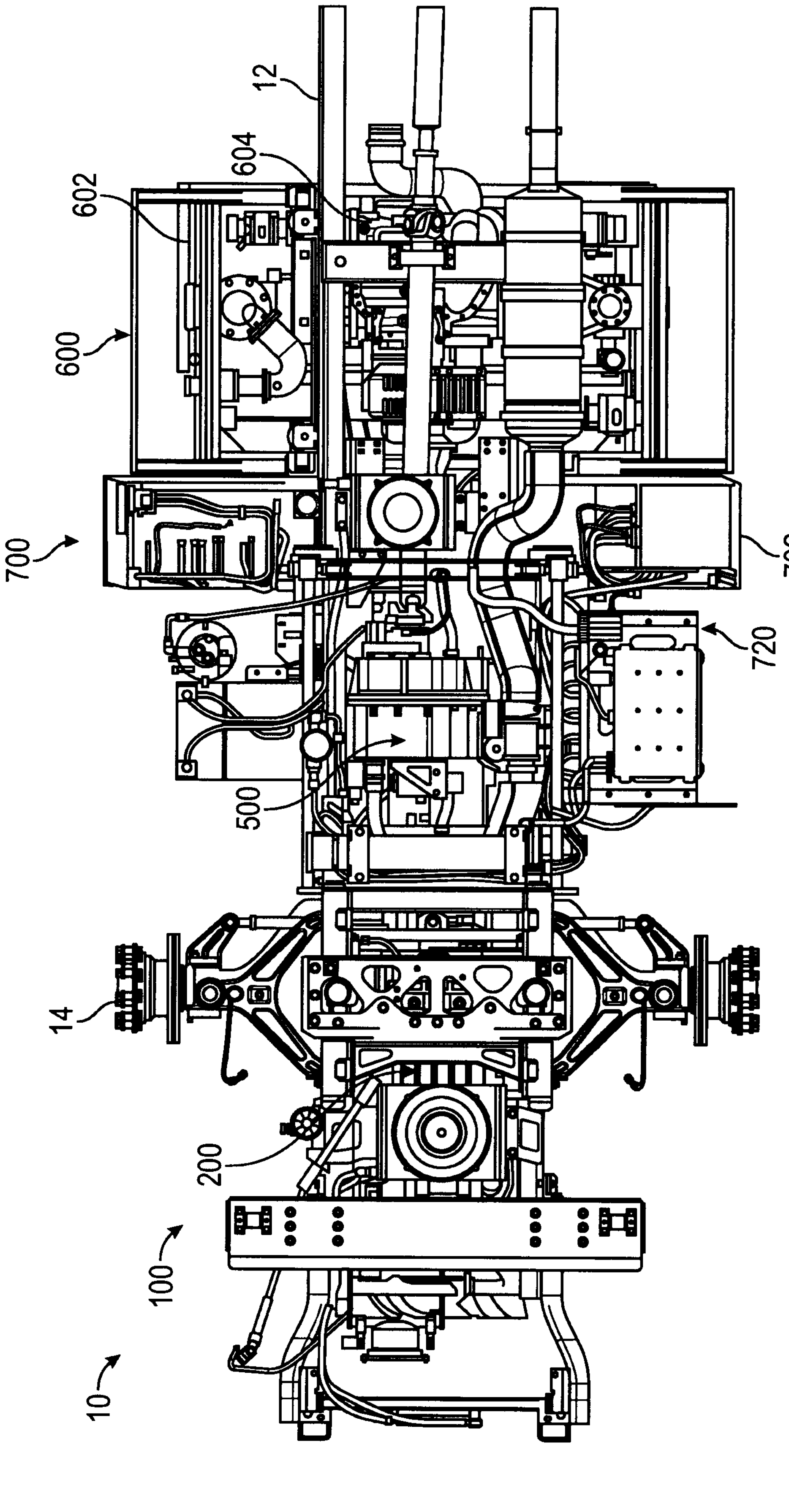

FIG. 12

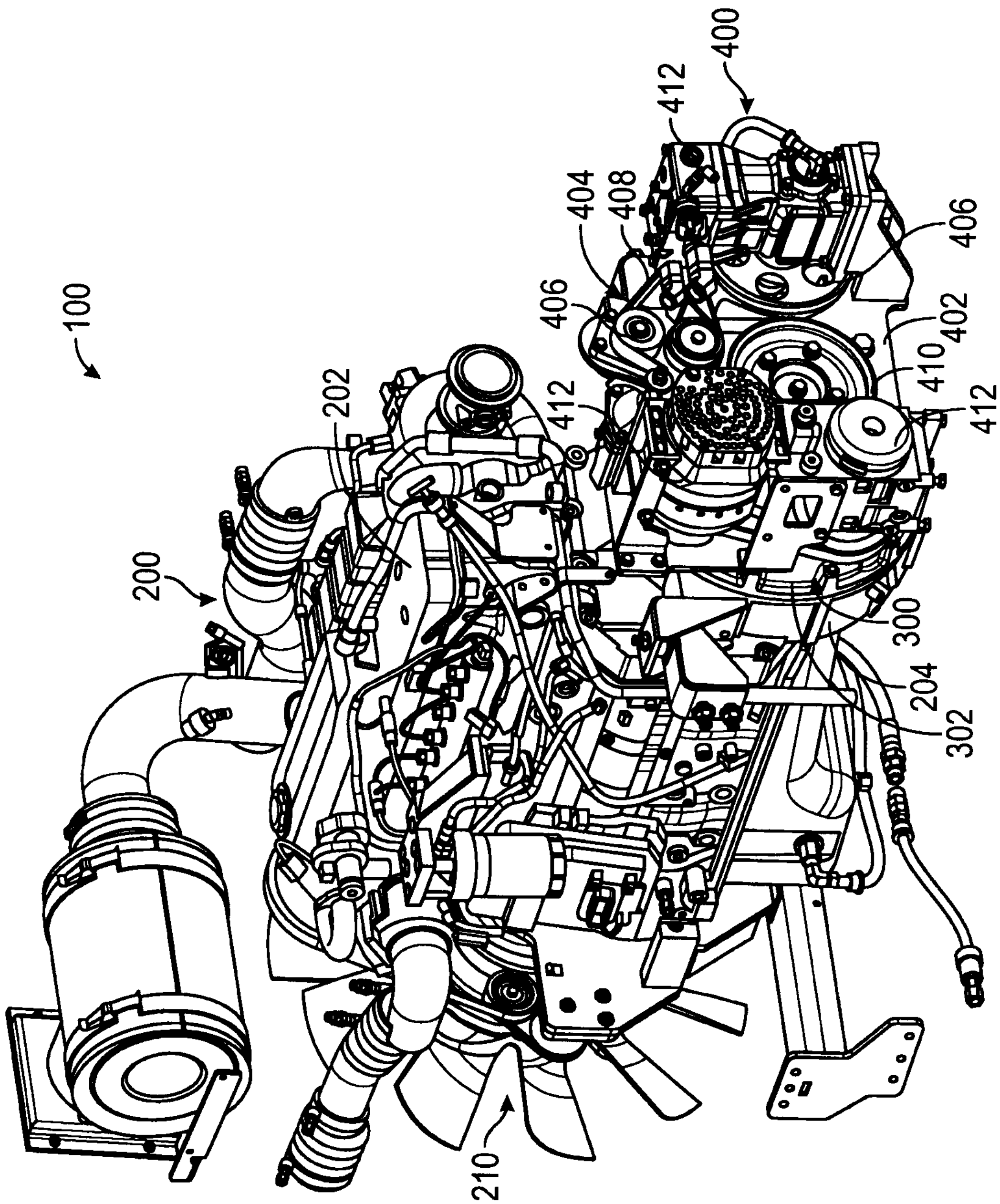
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FIG. 13

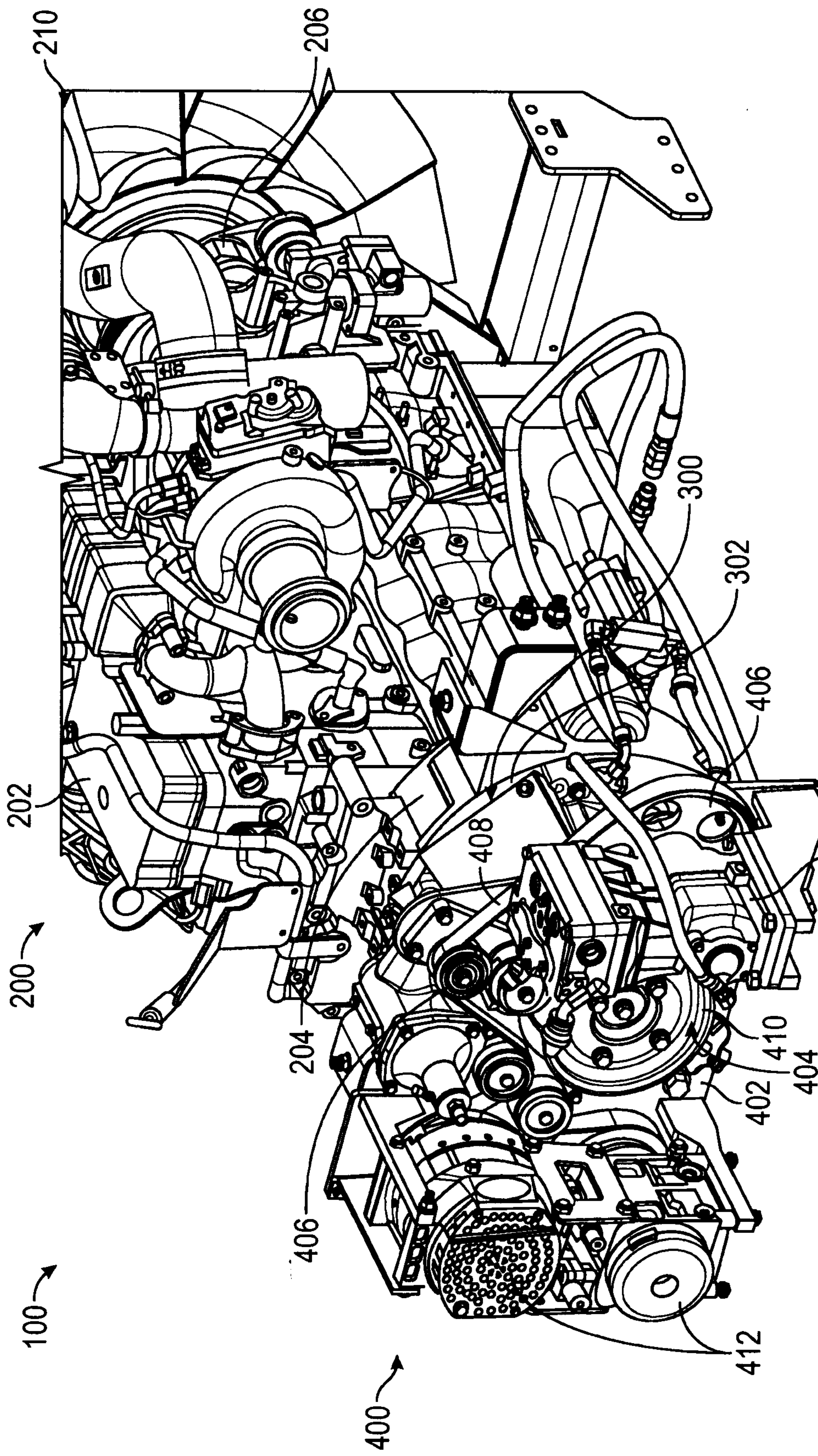
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FIG. 14

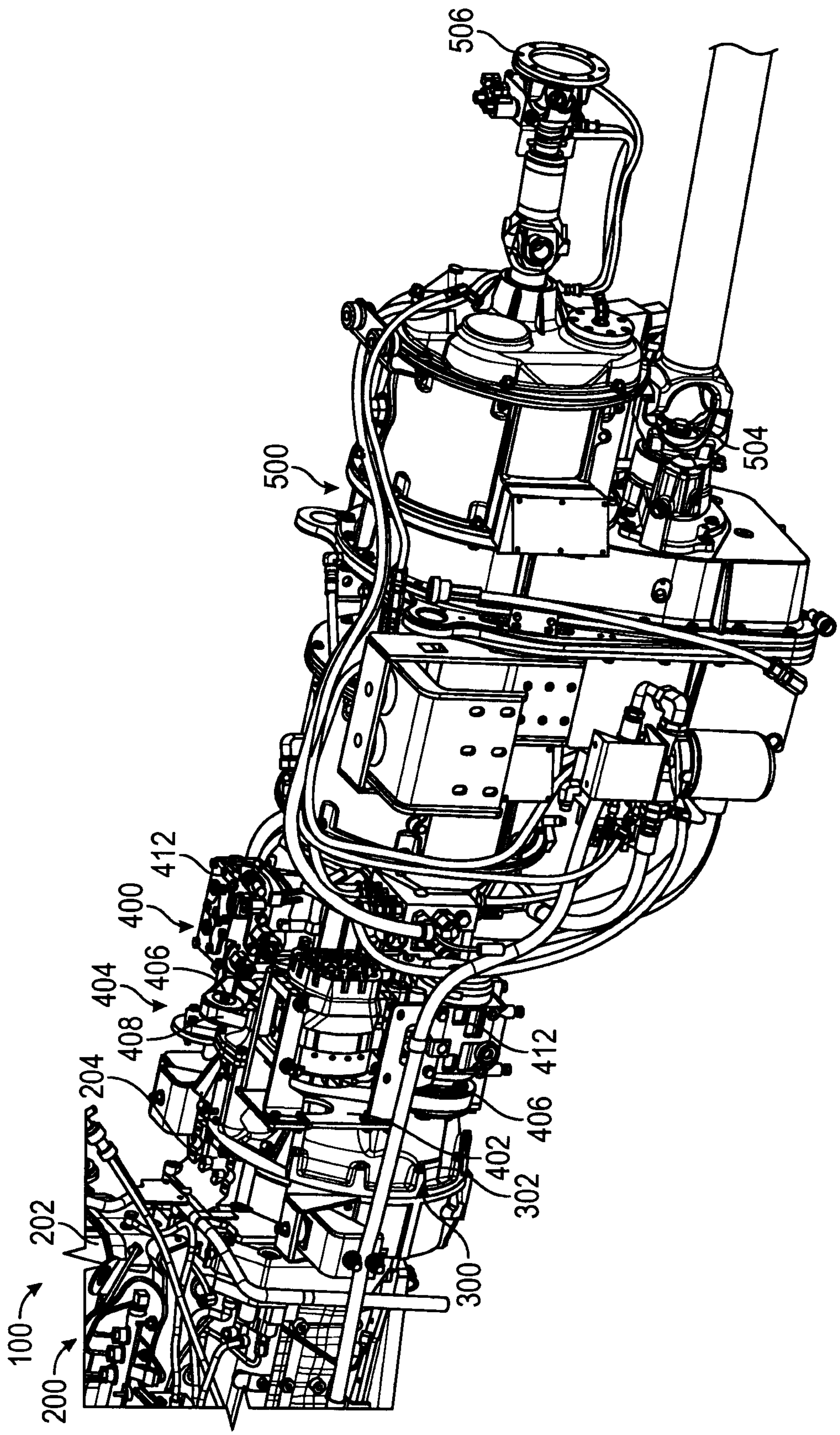
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FIG. 15

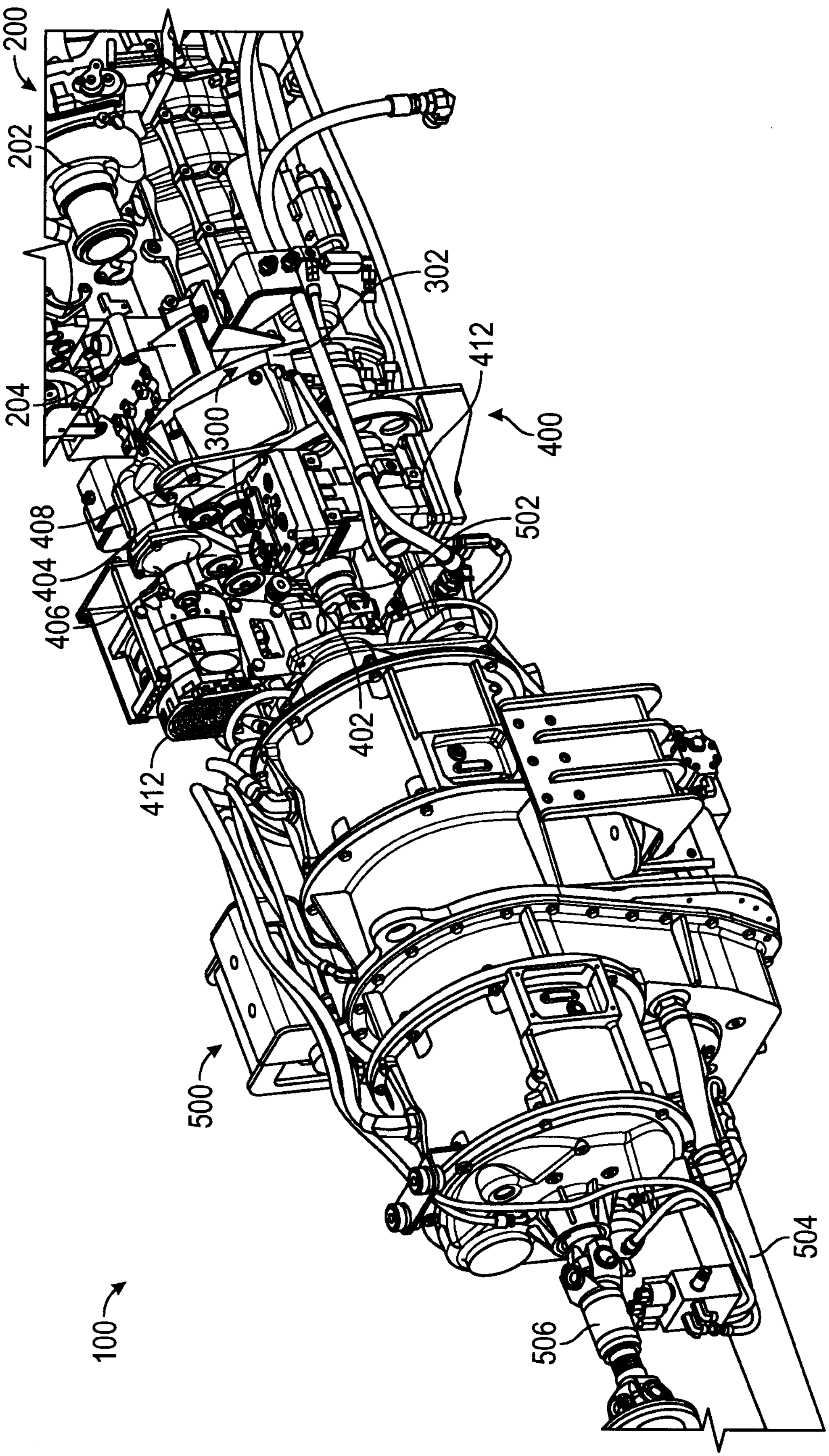
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FIG. 16

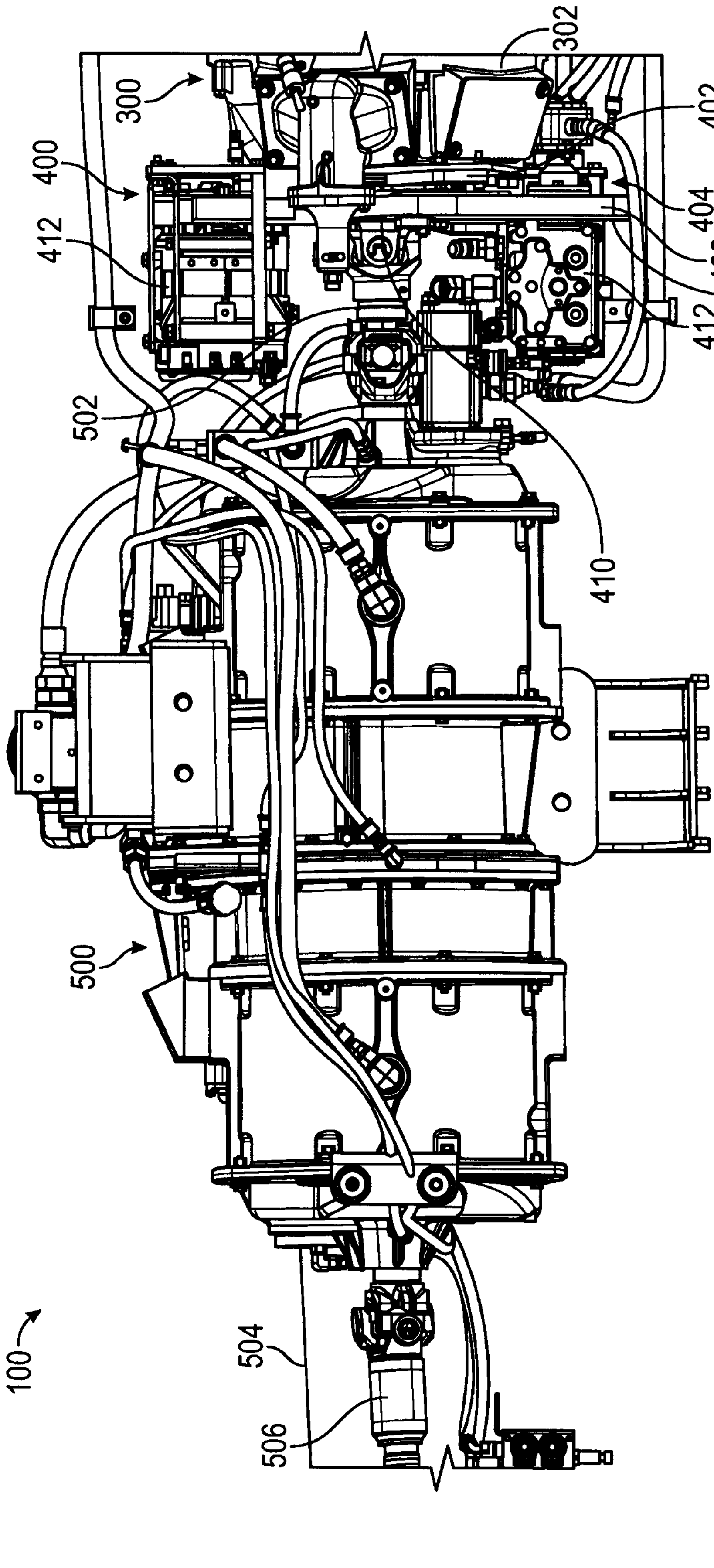

FIG. 17

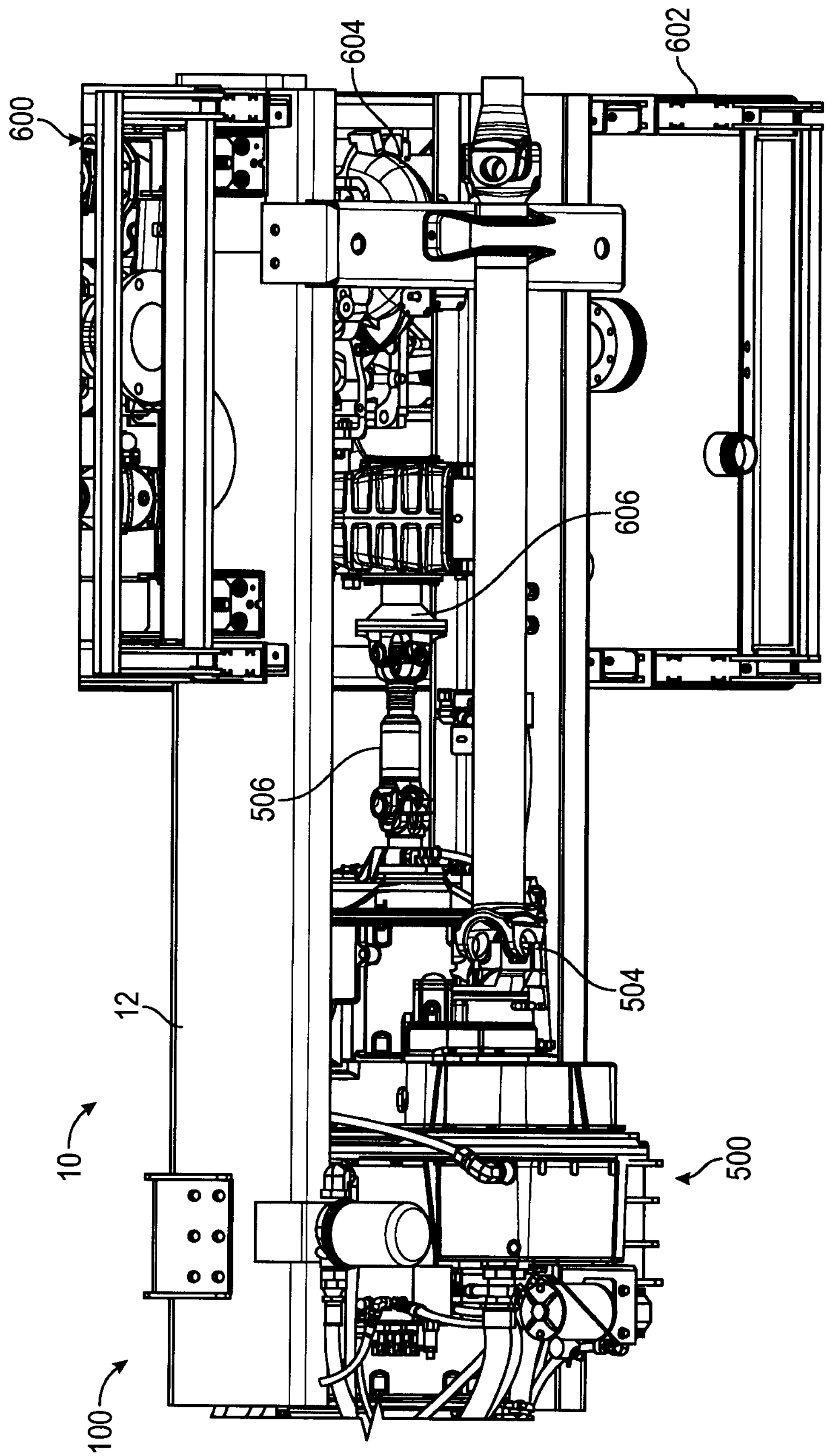

FIG. 18

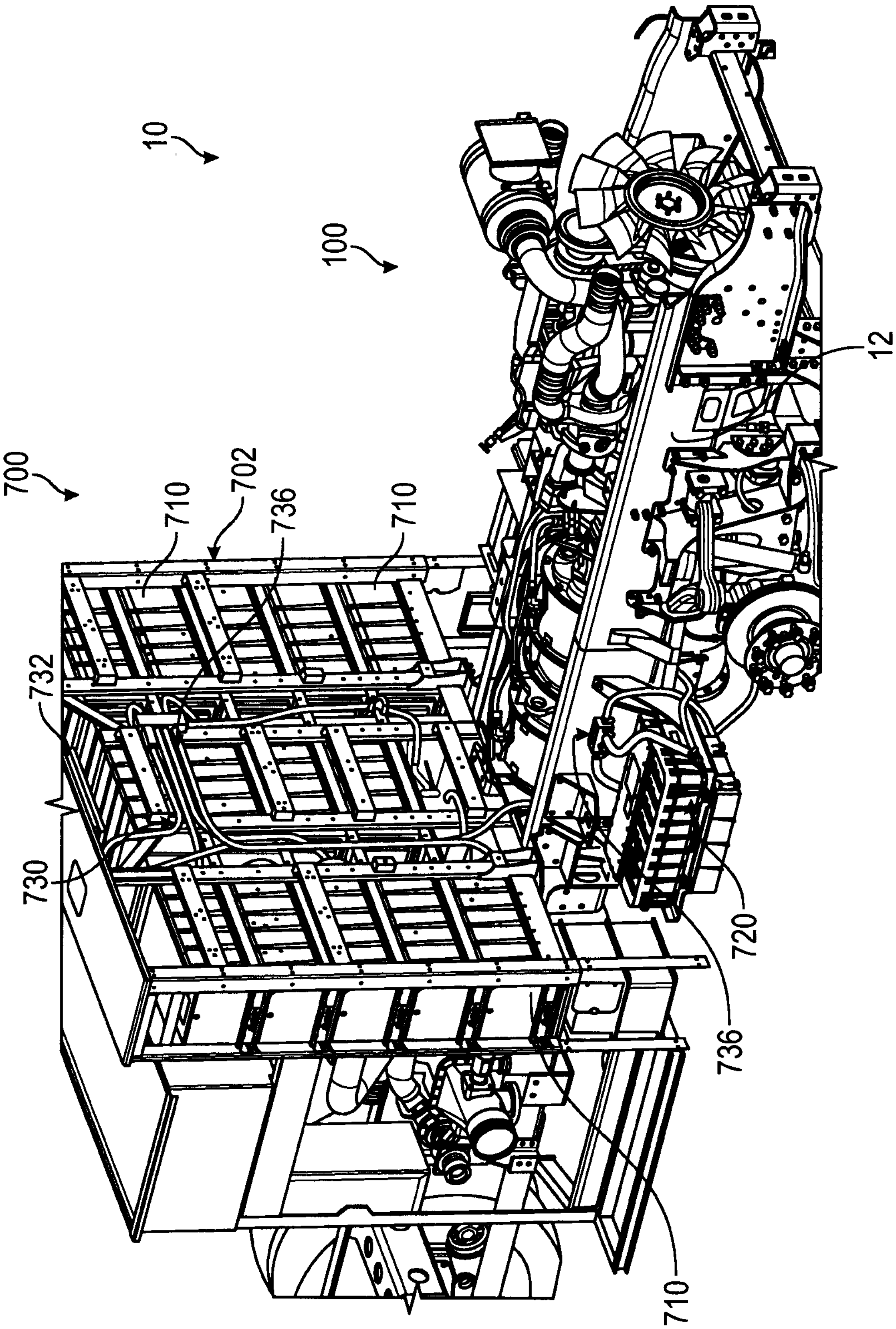

FIG. 19

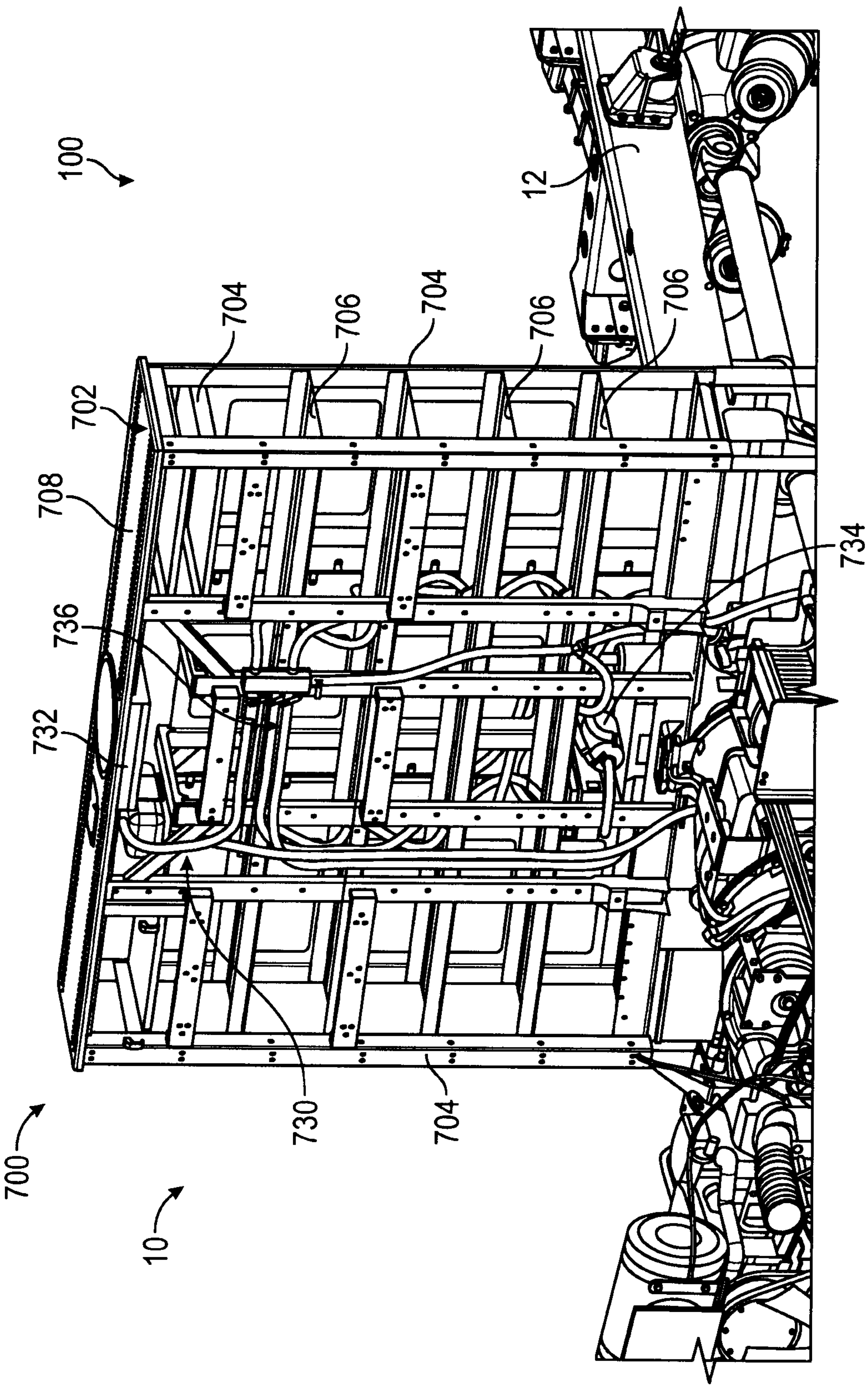

FIG. 20

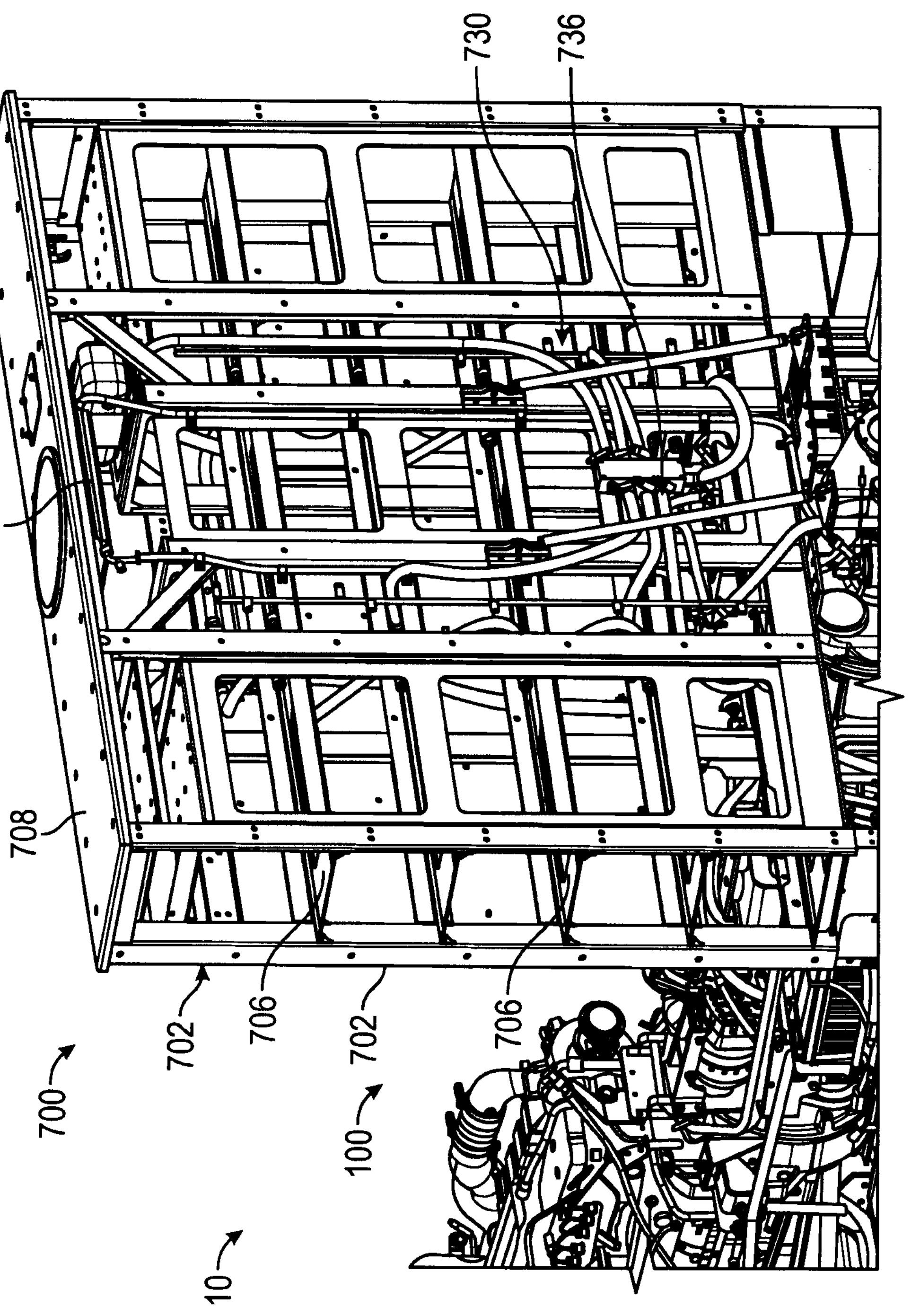

FIG. 21

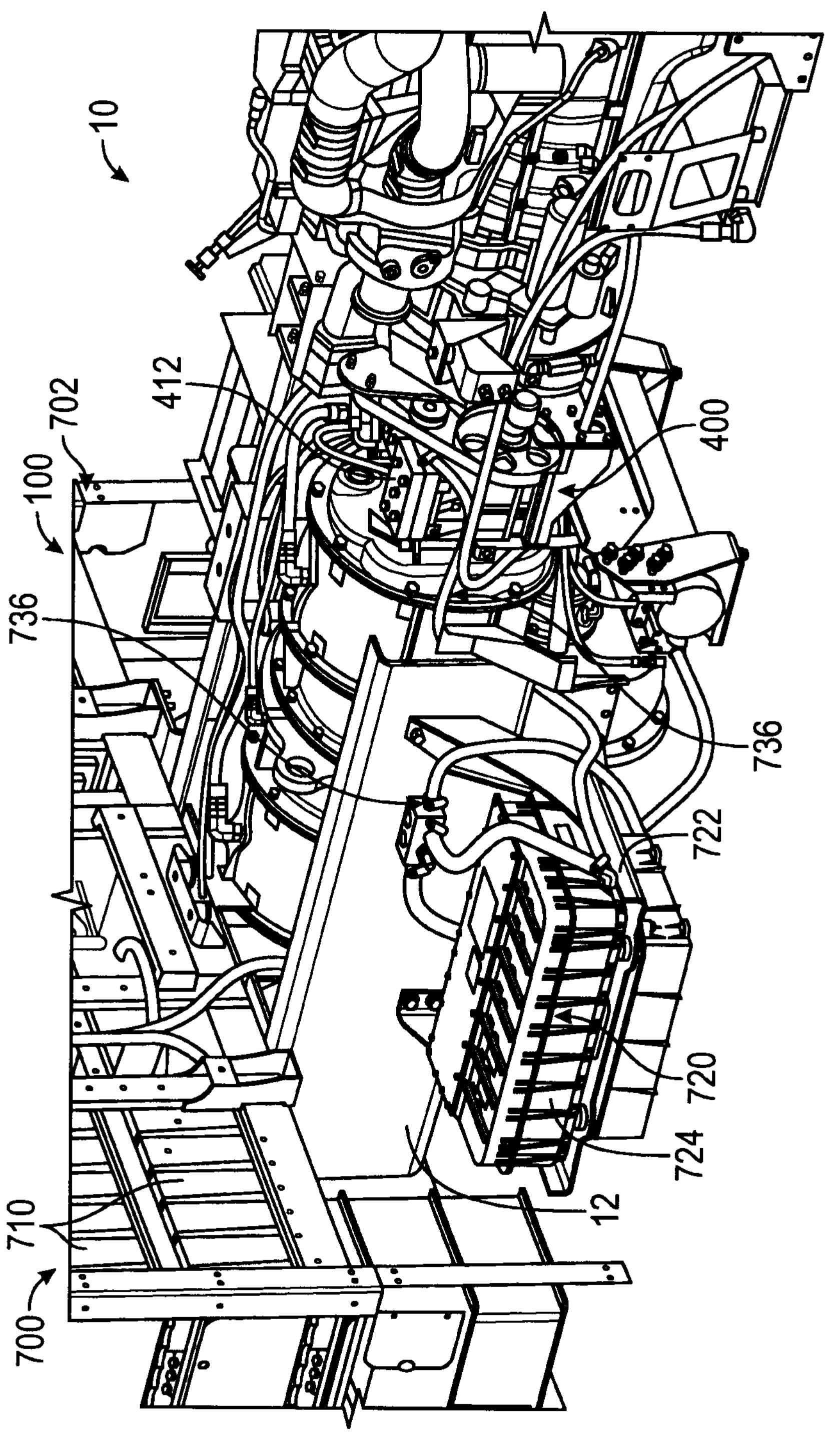

FIG. 22

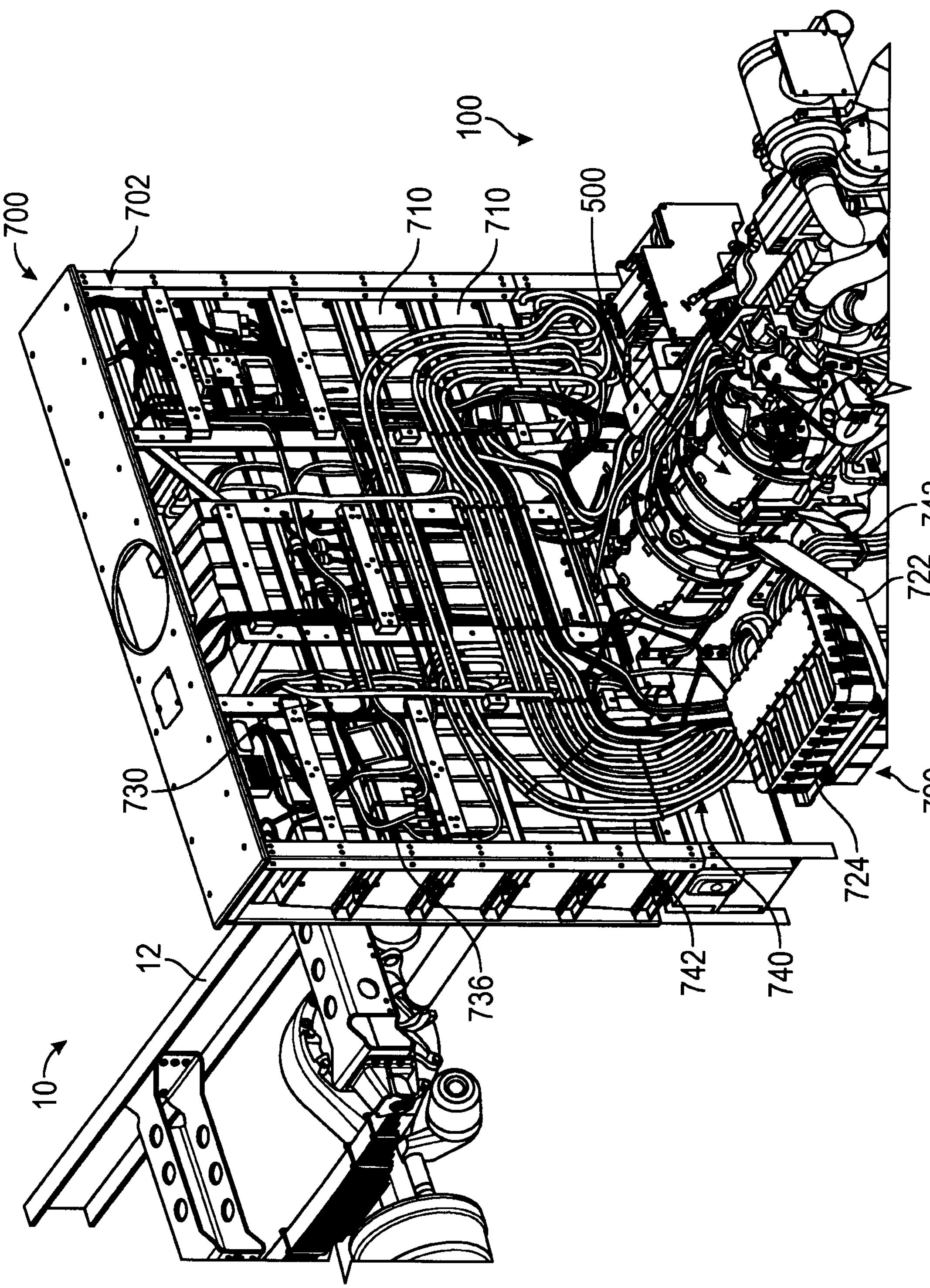

FIG. 23

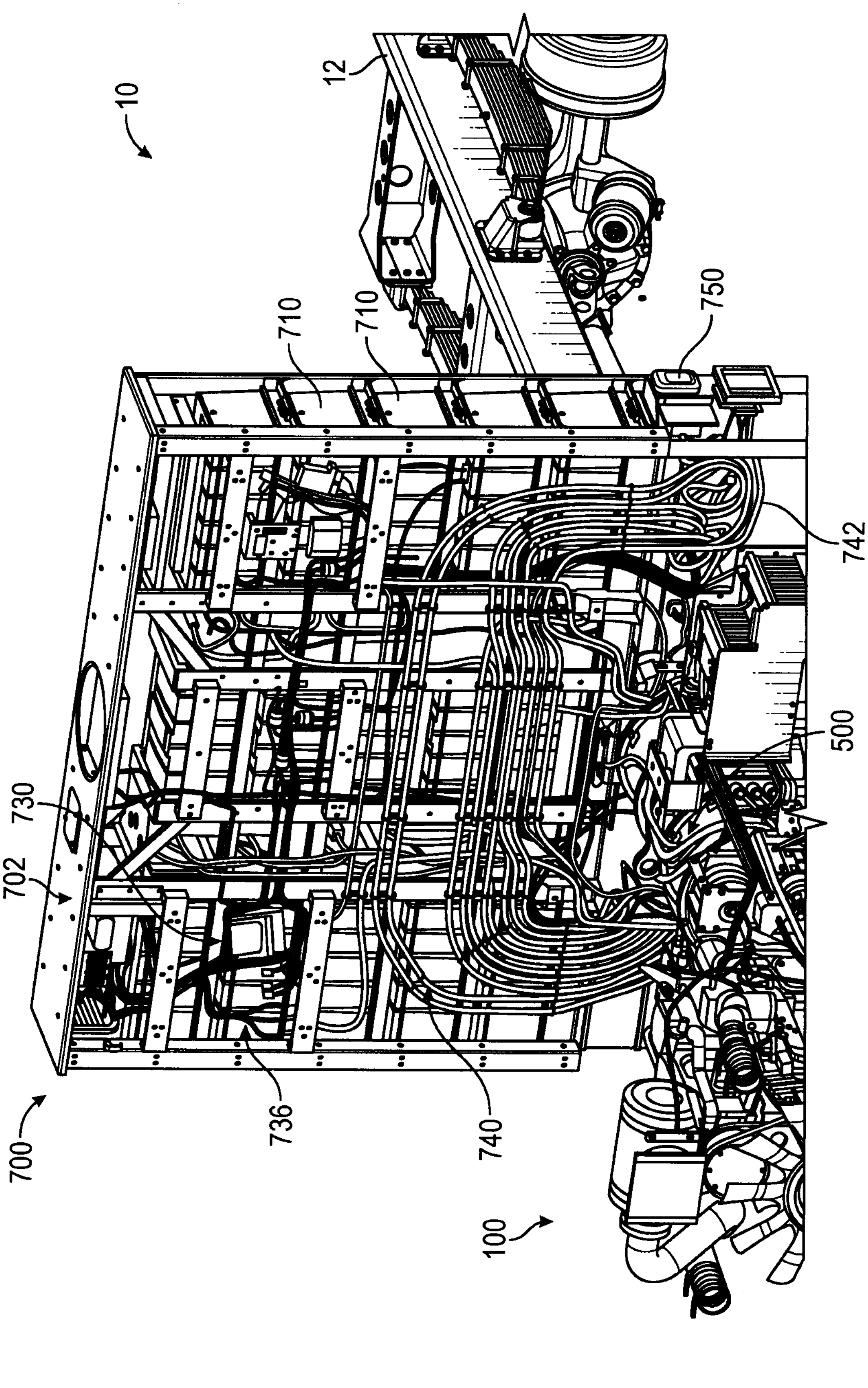

FIG. 24

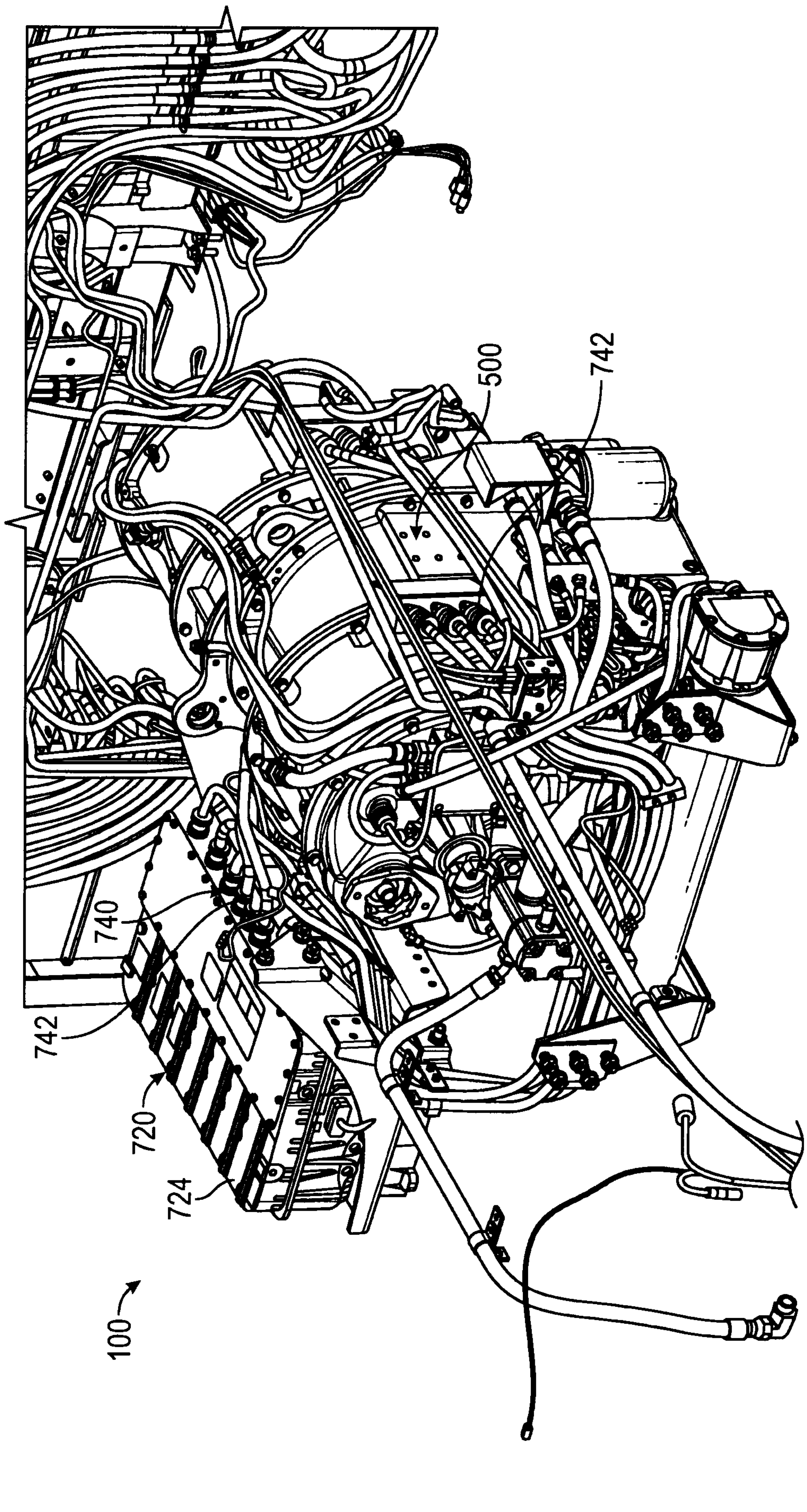

FIG. 25

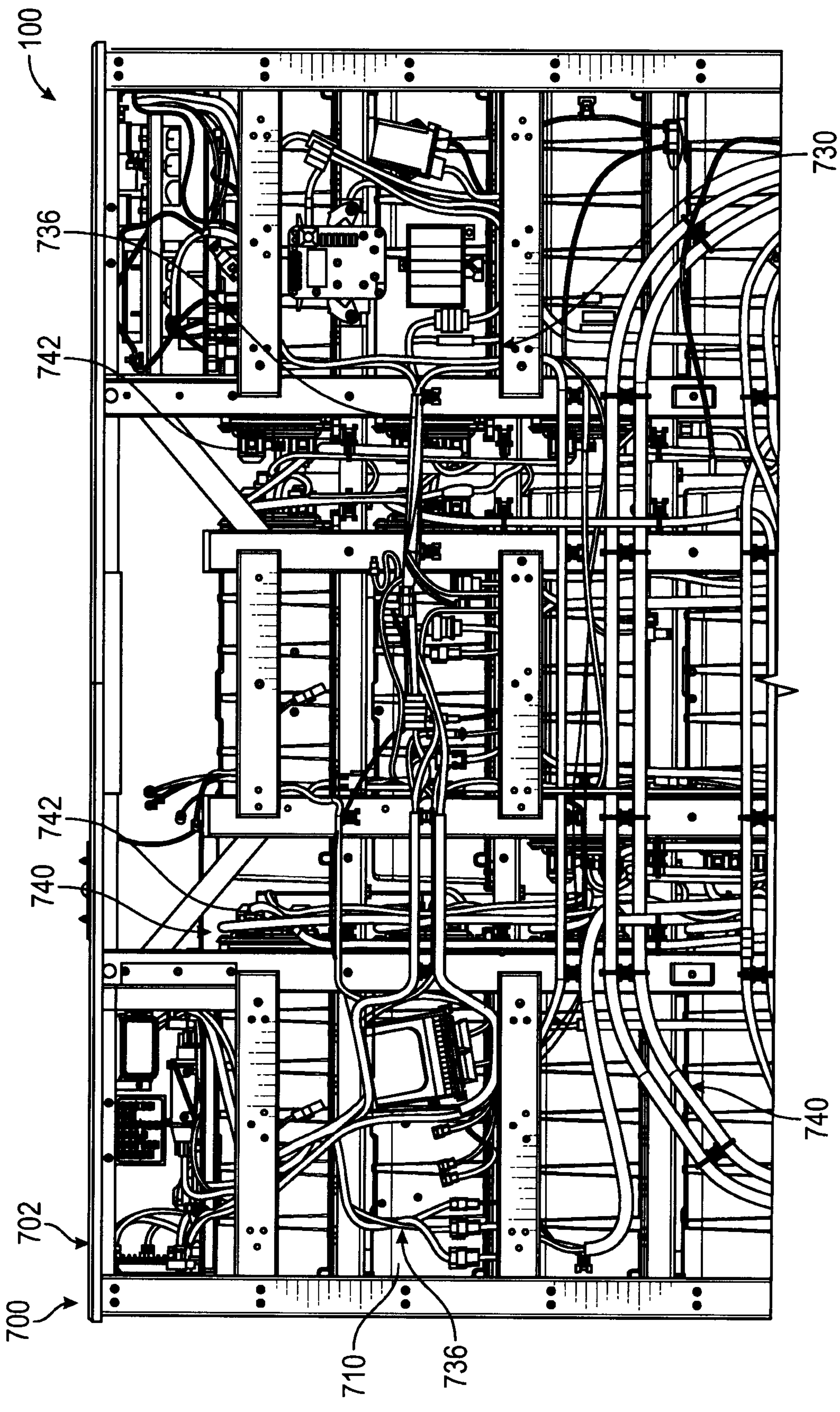

FIG. 26

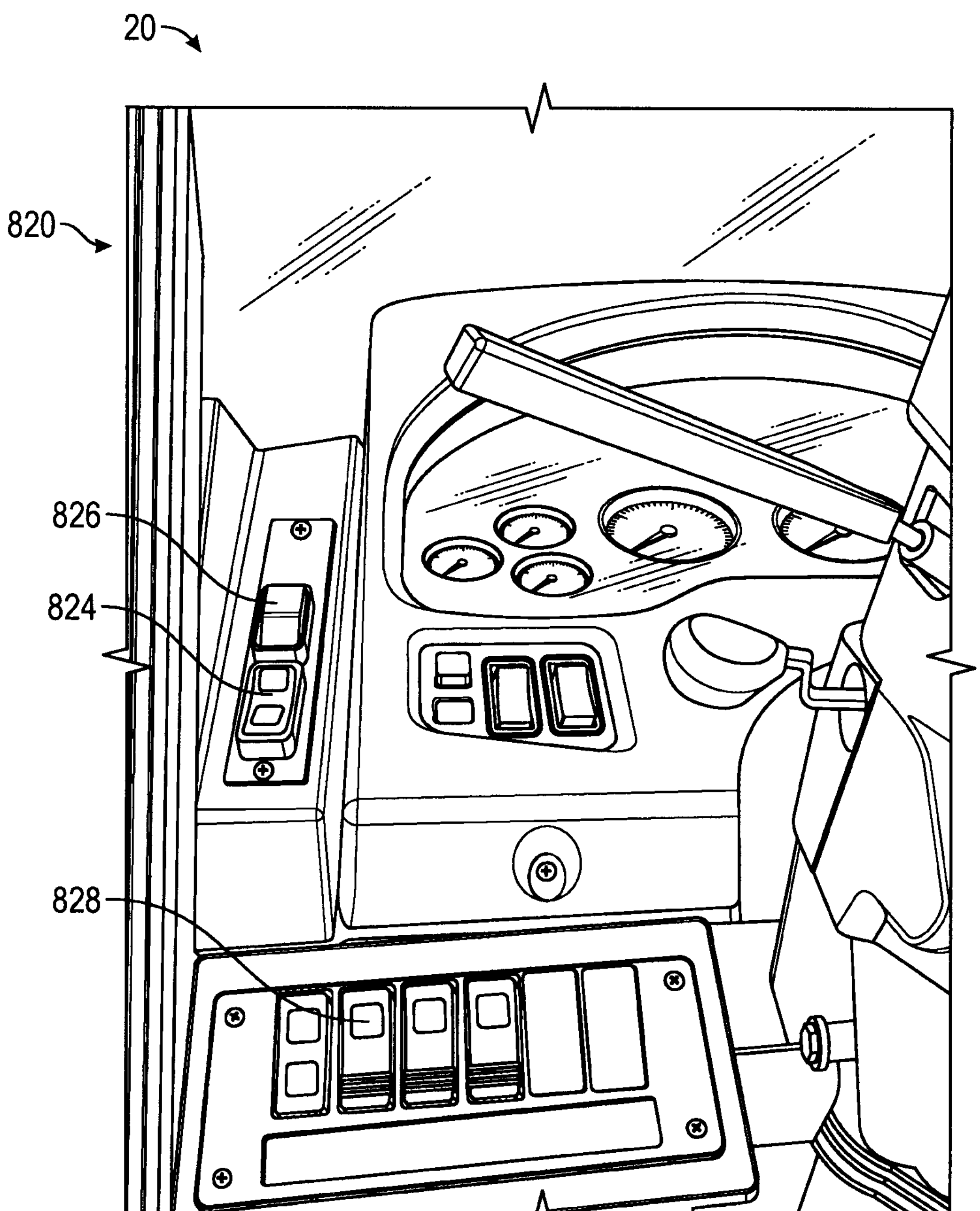

FIG. 27

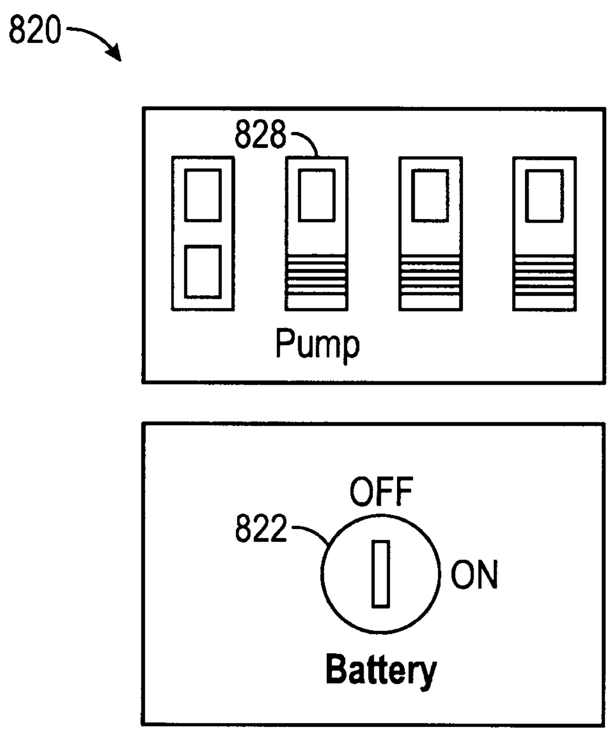

FIG. 28

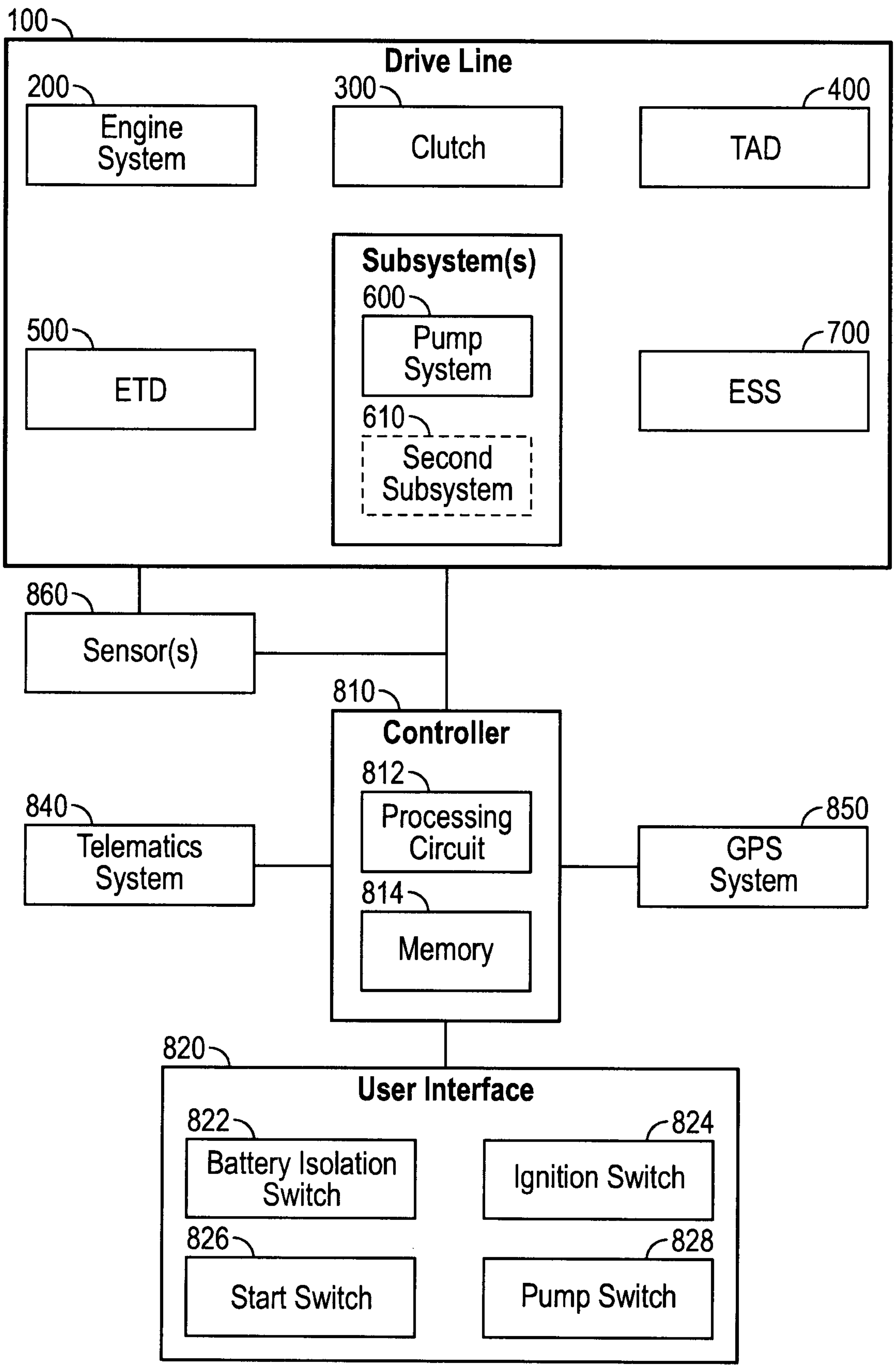
100
Drive Line
200
Engine System
300
Clutch
400
TAD
Subsystem(s)
600
Pump System
610
Second Subsystem
500
ETD
700
ESS
860
Sensor(s)
810
Controller
812
Processing Circuit
814
Memory
840
Telematics System
850
GPS System
820
User Interface
822
Battery Isolation Switch
824
Ignition Switch
826
Start Switch
828
Pump Switch

FIG. 29

OPERATIONAL MODES FOR A FIRE FIGHTING VEHICLE

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 17/492,106, filed Oct. 1, 2021, which claims the benefit of and priority to U.S. Provisional Patent Application No. 63/184,415, filed May 5, 2021, and U.S. Provisional Patent Application No. 63/250,676, filed Sep. 30, 2021, all of which are incorporated herein by reference in their entireties.

BACKGROUND

[0002] A fire fighting vehicle is a specialized vehicle designed to respond to fire scenes that can include various components to assist fire fighters with battling and extinguishing fires. Such components can include a pumping system, an onboard water tank, and an aerial ladder. Fire fighting vehicles traditionally include an internal combustion engine that provides power to both drive the vehicle and well as to drive the various components of the vehicle to facilitate the operation thereof.

SUMMARY

[0003] One embodiment relates to an electrified fire fighting vehicle. The electrified fire fighting vehicle includes a chassis, a cab coupled to the chassis, a body coupled to the chassis, a pump system, and a driveline. The driveline includes a front axle coupled to the chassis, a rear axle coupled to the chassis, an energy storage system, an engine coupled to the chassis, and an electromechanical device coupled to the chassis, the engine, and at least one of the front axle or the rear axle. The driveline is a dual drive driveline such that, during any and all modes of operation of the driveline, the electromechanical device is incapable of or prevented from charging the energy storage system at any time when driven by the engine.

[0004] Another embodiment relates to an electrified fire fighting vehicle. The electrified fire fighting vehicle includes a chassis, a cab coupled to the chassis, a body coupled to the chassis, a pump system, and a driveline. The driveline includes a front axle coupled to the chassis, a rear axle coupled to the chassis, an energy storage system, an engine coupled to the chassis, a clutched accessory drive, and an electromechanical device. The engine includes a first interface. The clutched accessory drive includes a clutch coupled to the first interface of the engine and an accessory drive coupled to the clutch. The accessory drive includes a plurality of accessories. The electromechanical device is coupled to the chassis and the energy storage system. The electromechanical device includes (a) a second interface coupled to the accessory drive such that the clutched accessory drive is positioned between the engine and the electromechanical device and (b) a third interface coupled to at least one of the front axle or the rear axle. The driveline is operable in a first mode where (a) the engine is off, (b) the clutch is disengaged to decouple the engine from the accessory drive and the electromechanical device, and (c) the electromechanical device uses stored energy in the energy storage system to drive (i) the at least one of the front axle or the rear axle via the third interface and (ii) the accessory drive via the second interface. The driveline is operable in a second mode where (a) the clutch is engaged, (b) the engine provides a mechanical input to the clutch via the first interface, which thereby drives the accessory drive and the second interface of the electromechanical device, (c) the electromechanical device uses the mechanical input received through the clutched accessory drive to drive the at least one of the front axle or the rear axle, and (d) the electromechanical device does not generate electricity to charge the energy storage system.

[0005] Still another embodiment relates to an electrified fire fighting vehicle. The electrified fire fighting vehicle includes a chassis, a cab coupled to the chassis, a body coupled to the chassis, a pump system, and a driveline. The driveline includes a front axle coupled to the chassis, a rear axle coupled to the chassis, an energy storage system, an engine coupled to the chassis and including a first interface, a clutched accessory drive, and an electromechanical device. The clutched accessory drive includes a clutch coupled to the first interface of the engine and an accessory drive coupled to the clutch. The accessory drive includes a plurality of accessories. The electromechanical device is coupled to the chassis and the energy storage system. The electromechanical device includes (a) a second interface coupled to the accessory drive such that the clutched accessory drive is positioned between the engine and the electromechanical device and (b) a third interface coupled to at least one of the front axle or the rear axle. The driveline is a dual drive driveline such that, during any and all modes of operation of the driveline, the electromechanical device does not charge the energy storage system at any time when driven by the engine.

[0006] This summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the devices or processes described herein will become apparent in the detailed description set forth herein, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a front, left perspective view of a fire fighting vehicle, according to an exemplary embodiment.

[0008] FIG. **2** is a front, right perspective view of the fire fighting vehicle of FIG. **1**, according to an exemplary embodiment.

[0009] FIG. **3** is a front view of the fire fighting vehicle of FIG. **1**, according to an exemplary embodiment.

[0010] FIG. **4** is a left side view of the fire fighting vehicle of FIG. **1**, according to an exemplary embodiment.

[0011] FIG. **5** is a right side view of the fire fighting vehicle of FIG. **1**, according to an exemplary embodiment.

[0012] FIG. **6** is a top view of the fire fighting vehicle of FIG. **1**, according to an exemplary embodiment.

[0013] FIG. **7** is a schematic diagram of a driveline of the fire fighting vehicle of FIG. **1** including an engine system, a clutch, an accessory drive, an electromechanical transmission, a pump system, an energy storage system, and one or more driven axles, according to an exemplary embodiment.

[0014] FIG. **8** is a front, left perspective view of a component layout of the driveline of FIG. **7**, according to an exemplary embodiment.

[0015] FIG. **9** is a front, right perspective view of the component layout of the driveline of FIG. **7**, according to an exemplary embodiment.

[0016] FIG. **10** is a side view of the component layout of the driveline of FIG. **7**, according to an exemplary embodiment.

[0017] FIG. **11** is a top view of the component layout of the driveline of FIG. **7**, according to an exemplary embodiment.

[0018] FIG. **12** is a bottom view of the component layout of the driveline of FIG. **7**, according to an exemplary embodiment.

[0019] FIGS. **13** and **14** are various perspective views of the engine system, the clutch, and the accessory drive of the driveline of FIG. **7**, according to an exemplary embodiment.

[0020] FIGS. **15** and **16** are various perspective views of the engine system, the clutch, the accessory drive, and the electromechanical transmission of the driveline of FIG. **7**, according to an exemplary embodiment.

[0021] FIG. **17** is a top view of the clutch, the accessory drive, and the electromechanical transmission of the driveline of FIG. **7**, according to an exemplary embodiment.

[0022] FIG. **18** is a bottom perspective view of the electromechanical transmission and the pump system of the driveline of FIG. **7**, according to an exemplary embodiment.

[0023] FIGS. **19-26** are various detailed views of the energy storage system of the driveline of FIG. **7**, according to an exemplary embodiment.

[0024] FIGS. **27** and **28** are various views of a user control interface within a cab of the fire fighting vehicle of FIG. **1**, according to an exemplary embodiment.

[0025] FIG. **29** is a schematic diagram of a control system of the fire fighting vehicle of FIG. **1**, according to an exemplary embodiment.

DETAILED DESCRIPTION

[0026] Before turning to the figures, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

[0027] According to an exemplary embodiment, a vehicle (e.g., a fire fighting vehicle, etc.) of the present disclosure includes a front axle, a rear axle, and a driveline having an engine, an electromechanical transmission, an energy storage system, a clutched accessory drive positioned between the engine and the electromechanical transmission, a subsystem (e.g., a pump system, an aerial ladder assembly, etc.) coupled to the electromechanical transmission, and at least one of the front axle or the rear axle coupled to the electromechanical transmission. In one embodiment, the driveline is configured a non-hybrid or "dual drive" driveline where electromechanical transmission does not generate energy for storage by the energy storage system. Rather, the energy storage system is chargeable from an external power source and not chargeable using the electromechanical transmission. In such a dual drive configuration, (i) the engine may mechanically drive (a) the clutched accessory drive directly and/or (b) the subsystem, the front axle, and/or the rear axle through the electromechanical transmission, (ii) the electromechanical transmission may mechanically drive (a) the clutched accessory drive, (b) the subsystem, (c) the front axle, and/or (d) the rear axle using stored energy in the energy storage system, or (iii) the engine may mechanically drive (a) the clutched accessory drive and (b) the electromechanical transmission directly and the electromechanical transmission may (a) generate electricity and (b) use the generated electricity (and, optionally, the stored electricity) to mechanically drive the subsystem, the front axle, and/or the rear axle. In another embodiment, the driveline is configured as a "hybrid" driveline where the electromechanical transmission is driven by the engine and generates energy for storage by the energy storage system. According to an exemplary embodiment, the vehicle includes a controller that is configured to operate the driveline in a plurality of modes of operations. The plurality of modes of operation (depending on whether the driveline is a "dual drive" driveline, is a "hybrid" driveline," or operable as a "dual drive" and a "hybrid" driveline) can include a pure engine mode, a pure electric mode, a charging mode, an electric generation drive mode, a boost mode, a distributed drive mode, a roll-out mode, a roll-in mode, a stop-start mode, a location tracking mode, a scene mode, a pump-and-roll mode, and/or still other modes, as described in greater detail herein.

Overall Vehicle

[0028] According to the exemplary embodiment shown in FIGS. **1-6**, a machine, shown vehicle **10**, is configured as a fire fighting vehicle. In the embodiment shown, the fire fighting vehicle is a pumper fire truck. In another embodiment, the fire fighting vehicle is an aerial ladder truck. The aerial ladder truck may include a rear-mount aerial ladder or a mid-mount aerial ladder. In some embodiments, the aerial ladder truck is a quint fire truck. In other embodiments, the aerial ladder truck is a tiller fire truck. In still another embodiment, the fire fighting vehicle is an airport rescue fire fighting ("ARFF") truck. In various embodiments, the fire fighting vehicle (e.g., a quint, a tanker, an ARFF, etc.) includes an on-board water storage tank, an on-board agent storage tank, and/or a pumping system. In other embodiments, the fire fighting vehicle is still another type of fire fighting vehicle. In an alternative embodiment, the vehicle **10** is another type of vehicle other than a fire fighting vehicle. For example, the vehicle **10** may be a refuse truck, a concrete mixer truck, a military vehicle, a tow truck, an ambulance, a farming machine or vehicle, a construction machine or vehicle, and/or still another vehicle.

[0029] As shown in FIGS. **1-26**, the vehicle **10** includes a chassis, shown as a frame **12**; a plurality of axles, shown as front axle **14** and rear axle **16**, supported by the frame **12** and that couple a plurality of tractive elements, shown as wheels **18**, to the frame **12**; a cab, shown as front cabin **20**, supported by the frame **12**; a body assembly, shown as a rear section **30**, supported by the frame **12** and positioned rearward of the front cabin **20**; and a driveline (e.g., a powertrain, a drivetrain, an accessory drive, etc.), shown as driveline **100**. While shown as including a single front axle **14** and a single rear axle **16**, in other embodiments, the vehicle **10** includes two front axles **14** and/or two rear axles **16**. In an alternative embodiment, the tractive elements are otherwise structured (e.g., tracks, etc.).

[0030] According to an exemplary embodiment, the front cabin **20** includes a plurality of body panels coupled to a support (e.g., a structural frame assembly, etc.). The body panels may define a plurality of openings through which an operator accesses an interior **24** of the front cabin **20** (e.g., for ingress, for egress, to retrieve components from within, etc.). As shown in FIGS. **1**, **2**, **4**, and **5**, the front cabin **20**

includes a plurality of doors, shown as doors **22**, positioned over the plurality of openings defined by the plurality of body panels. The doors **22** may provide access to the interior **24** of the front cabin **20** for a driver and/or passengers of the vehicle **10**. The doors **22** may be hinged, sliding, or bus-style folding doors.

[0031] The front cabin **20** may include components arranged in various configurations. Such configurations may vary based on the particular application of the vehicle **10**, customer requirements, or still other factors. The front cabin **20** may be configured to contain or otherwise support a number of occupants, storage units, and/or equipment. For example, the front cabin **20** may provide seating for an operator (e.g., a driver, etc.) and/or one or more passengers of the vehicle **10**. The front cabin **20** may include one or more storage areas for providing compartmental storage for various articles (e.g., supplies, instrumentation, equipment, etc.). The interior **24** of the front cabin **20** may further include a user interface (e.g., user interface **820**, etc.). The user interface may include a cabin display and various controls (e.g., buttons, switches, knobs, levers, joysticks, etc.). In some embodiments, the user interface within the interior **24** of the front cabin **20** further includes touch-screens, a steering wheel, an accelerator pedal, and/or a brake pedal, among other components. The user interface may provide the operator with control capabilities over the vehicle **10** (e.g., direction of travel, speed, etc.), one or more components of driveline **100**, and/or still other components of the vehicle **10** from within the front cabin **20**.

[0032] In some embodiments, the rear section **30** includes a plurality of compartments with corresponding doors positioned along one or more sides (e.g., a left side, right side, etc.) and/or a rear of the rear section **30**. The plurality of compartments may facilitate storing various equipment such as oxygen tanks, hoses, axes, extinguishers, ladders, chains, ropes, straps, boots, jackets, blankets, first-aid kits, and/or still other equipment. One or more of the plurality of compartments may include various storage apparatuses (e.g., shelving, hooks, racks, etc.) for storing and organizing the equipment.

[0033] In some embodiments (e.g., when the vehicle **10** is an aerial ladder truck, etc.), the rear section **30** includes an aerial ladder assembly. The aerial ladder assembly may have a fixed length or may have one or more extensible ladder sections. The aerial ladder assembly may include a basket or implement (e.g., a water turret, etc.) coupled to a distal or free end thereof. The aerial ladder assembly may be positioned proximate a rear of the rear section **30** (e.g., a rear-mount fire truck) or proximate a front of the rear section **30** (e.g., a mid-mount fire truck).

[0034] In some embodiments (e.g., when the vehicle **10** is an ARFF truck, a tanker truck, a quint truck, etc.), the rear section **30** includes one or more fluid tanks. By way of example, the one or more fluid tanks may include a water tank and/or an agent tank. The water tank and/or the agent tank may be corrosion and UV resistant polypropylene tanks. In a municipal fire truck implementation (i.e., a non-ARFF truck implementation), the water tank may have a maximum water capacity ranging between 50 and 1000 gallons (e.g., 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000, etc. gallons). In an ARRF truck implementation, the water tank may have a maximum water capacity ranging between 1,000 and 4,500 gallons (e.g., at least 1,250 gallons; between 2,500 gallons and 3,500 gallons; at most 4,500 gallons; at most 3,000 gallons; at most 1,500 gallons; etc.). The agent tank may have a maximum agent capacity ranging between 25 and 750 gallons (e.g., 25, 50, 75, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, etc. gallons). According to an exemplary embodiment, the agent is a foam fire suppressant, an aqueous film forming foam ("AFFF"). A low-expansion foam, a medium-expansion foam, a high-expansion foam, an alcohol-resistant foam, a synthetic foam, a protein-based foams, a fluorine-free foam, a film-forming fluoro protein ("FFFP") foam, an alcohol resistant aqueous film forming foam ("AR-AFFF"), and/or still another suitable foam or a foam yet to be developed. The capacity of the water tank and/or the agent tank may be specified by a customer. It should be understood that water tank and the agent tank configurations are highly customizable, and the scope of the present disclosure is not limited to a particular size or configuration of the water tank and the agent tank.

Driveline

[0035] As shown in FIGS. **1-26**, the driveline **100** includes an engine assembly, shown as engine system **200**, coupled to the frame **12**; a clutched transmission accessory drive ("TAD") including a first component, shown as clutch **300**, coupled to the engine system **200** and a second component (e.g., an accessory module, etc.), shown as TAD **400**, coupled to the clutch **300**; an electromechanical transmission or electromechanical transmission device ("ETD"), shown as ETD **500**, coupled to the TAD **400**; one or more subsystems including a first subsystem, shown as pump system **600**, coupled to the frame **12** and the ETD **500**; and an on-board energy storage system ("ESS"), shown as ESS **700**, coupled to the frame **12** and electrically coupled to the ETD **500**. According to an exemplary embodiment, the engine system **200**, the clutch **300**, the ETD **500**, and/or the ESS **700** are controllable to drive the vehicle **10**, the TAD **400**, the pump system **600**, and/or other accessories or components of the vehicle **10** (e.g., an aerial ladder assembly, etc.).

[0036] In one embodiment, the driveline **100** is configured or selectively operable as a non-hybrid or "dual drive" driveline where the ETD **500** is configured or controlled such that the ETD **500** does not generate electricity for storage in the ESS **700**. By way of example, the driveline **100** may be operable in a pure electric mode where the engine system **200** is turned off and the ETD **500** uses stored energy from the ESS **700** to drive one or more component of the vehicle **10** (e.g., the front axle **14**, the rear axle **16**, the pump system **600**, an aerial ladder assembly, the TAD **400**, etc.). By way of another example, the driveline **100** may be operable in a pure engine mode where the ETD **500** functions as a mechanical conduit or power divider between the engine system **200** and one or more components of the vehicle **10** (e.g., the front axle **14**, the rear axle **16**, the pump system **600**, an aerial ladder assembly, etc.) when the engine system **200** is in operation. By way of yet another example, the driveline **100** may be operable in an electric generation drive mode where the engine system **200** drives the ETD **500** to generate electricity and the ETD **500** uses the generated electricity to drive one or more component of the vehicle **10** (e.g., the front axle **14**, the rear axle **16**, the pump system **600**, an aerial ladder assembly, etc.). By way of yet another example, the driveline **100** may be operable in a boost mode that is similar to the electric generation drive mode, but the

ETD **500** draws additional power from the ESS **700** to supplement the generated electricity. By way of still yet another example, the driveline **100** may be operable in distributed drive mode where both the engine system **200** and the ETD **500** are simultaneously operable to drive one or more components of the vehicle **10** (i.e., the engine system **200** consumes fuel in a fuel tank and the ETD **500** consumes stored energy in the ESS **700**). For example, the engine system **200** may drive the TAD **400** and the ETD **500** may drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or an aerial ladder assembly. In such operation, the ETD **500** may include an ETD clutch that facilitates decoupling the ETD **500** from the TAD **400**. In another embodiment, the driveline **100** is configured or selectively operable as a "hybrid" driveline where the ETD **500** is configured or controlled such that the ETD **500** generates electricity for storage in the ESS **700**. By way of example, the driveline **100** may be operable in a charging mode where the engine system **200** drives the ETD **500** to generate electricity for storage in the ESS **700** and, optionally, to power one or more electrically-operated accessories or components of the vehicle **10** and/or for use by the ETD **500** to drive one or more component of the vehicle **10** (e.g., the front axle **14**, the rear axle **16**, the pump system **600**, an aerial ladder assembly, etc.).

Engine System

[0037] As shown in FIGS. **3** and **8-12**, the engine system **200** is coupled to the frame **12** and positioned beneath the front cabin **20**. In another embodiment, the engine system **200** is otherwise positioned (e.g., beneath or within the rear section **30**, etc.). As shown in FIGS. **13-16**, the engine system **200** includes a prime mover, shown as engine **202**, and a first cooling assembly, shown as engine cooling system **210**. According to an exemplary embodiment, the engine **202** is a compression-ignition internal combustion engine that utilizes diesel fuel. In alternative embodiments, the engine **202** is a spark-ignition engine that utilizes one of a variety of fuel types (e.g., gasoline, compressed natural gas, propane, etc.).

[0038] As shown in FIGS. **13-16**, the engine **202** includes a first interface (e.g., a first output, etc.), shown as clutch interface **204**, coupled to the clutch **300** (e.g., an input shaft thereof, etc.) and a second interface (e.g., a second output, etc.), shown as cooling system interface **206**, coupled to the engine cooling system **210**. According to an exemplary embodiment, the clutch **300** is controllable (e.g., engaged, disengaged, etc.) to facilitate selectively mechanically coupling the engine **202** to and selectively mechanically decoupling the engine **202** from the TAD **400**. Accordingly, the engine **202** may be operated to drive the TAD **400** when the clutch **300** is engaged to couple the engine **202** to the TAD **400**. According to an exemplary embodiment, the engine cooling system **210** includes various components such as a fan, a pulley assembly, a radiator, conduits, etc. to provide cooling to the engine **202**. The fan may be coupled to the cooling system interface **206** of the engine **202** (e.g., directly, indirectly via a pulley assembly, etc.) and driven thereby.

Accessory Drive

[0039] As shown in FIGS. **13-17**, the TAD **400** includes (i) a base or frame, shown as accessory base **402**, coupled to a housing, shown as clutch housing **302**, of the clutch **300**, (ii) a pulley assembly, shown as accessory pulley assembly **404**, coupled to (e.g., supported by, extending from, etc.) the accessory base **402**, and (iii) a plurality of accessories, shown as accessories **412**, coupled to the accessory pulley assembly **404** and supported by the accessory base **402**. The accessory pulley assembly **404** includes a plurality of pulleys, shown as accessory pulleys **406**, coupled to the accessory base **402** and the accessories **412**; a belt, shown as accessory belt **408**; and an input pulley, shown as drive pulley **410**, coupled to (i) the clutch **300** (e.g., an output shaft thereof, etc.) and (ii) the accessory pulleys **406** by the accessory belt **408**. Accordingly, the drive pulley **410** can be selectively driven by the engine **202** through the clutch **300** and, thereby, the engine **202** can selectively drive the accessory pulley assembly **404** to drive the accessories **412**. According to an exemplary embodiment, the accessories **412** include an air-conditioning compressor, an air compressor, a power steering pump, and/or an alternator. In some embodiments, the accessories include additional, fewer, and/or different accessories that are capable of being mechanically driven.

Electromechanical Transmission Device

[0040] As shown in FIGS. **4**, **5**, **8**, **9**, **11**, and **12**, the ETD **500** is coupled to the frame **12** and positioned beneath the front cabin **20**, rearward of the engine **202**, the clutch **300**, and the TAD **400**. In another embodiment, the ETD **500** is otherwise positioned (e.g., beneath or within the rear section **30**, etc.). As shown in FIGS. **7** and **15-18**, the ETD **500** includes a first interface (e.g., a first input/output, etc.), shown as accessory drive interface **502**, coupled to the drive pulley **410** of the TAD **400** (e.g., via an accessory drive shaft, etc.); a second interface (e.g., a second output, etc.), shown as axle interface **504**, coupled (e.g., directly, indirectly, etc.) to the front axle **14** (e.g., a front differential thereof via a front drive shaft, etc.) and/or the rear axle **16** (e.g., a rear differential thereof via a rear drive shaft, etc.); and a third interface (e.g., a third output, a power-take-off ("PTO"), etc.), shown as subsystem interface **506**, coupled to the pump system **600** (e.g., via a subsystem drive shaft, etc.) and/or a second subsystem **610**.

[0041] In one embodiment, the axle interface **504** includes a single output directly coupled to the front axle **14** or the rear axle **16** such that only one of the front axle **14** or the rear axle **16** is driven. In another embodiment, the axle interface **504** includes two separate outputs, one directly coupled to each of the front axle **14** and the rear axle **16** such that both the front axle **14** and the rear axle **16** are driven. In some embodiments, as shown in FIG. **7**, the driveline **100** includes a first power divider, shown as transfer case **530**, and the axle interface **504** includes a single output coupled to an input of the transfer case **530**. The transfer case **530** may include a first output coupled to the front axle **14** and a second output coupled to the rear axle **16** to facilitate driving the first axle **14** and the rear axle **16** with the ETD **500**. In some embodiments, as shown in FIG. **7**, the driveline **100** includes a second power divider, show as power divider **540**, and the subsystem interface **506** is coupled to an input of the power divider **540**. The power divider **540** may include a plurality of outputs coupled to a plurality of subsystems (e.g., the pump system **600**, an aerial ladder assembly, the second subsystem **610**, etc.) to facilitate selectively driving each of the plurality of subsystems with the ETD **500**.

According to an exemplary embodiment, the ETD **500** is configured such that the subsystem interface **506** and the axle interface **504** are speed independent. Therefore, the subsystems (e.g., the pump system **600**, the aerial ladder assembly, the second subsystem **610**, etc.) can be driven with the ETD **500** at a speed independent of the ground speed of the vehicle **10**.

[0042] As shown in FIG. **7**, the ETD **500** is electrically coupled to the ESS **700**. According to an exemplary embodiment, such electrical connection facilitates electrically operating the ETD **500** using stored energy in the ESS **700** to drive the front axle **14**, the rear axle **16**, the TAD **400**, the pump system **600**, and/or another subsystem (e.g., the second subsystem **610**). In some embodiments (e.g., in embodiments where the driveline **100** is a hybrid driveline or is selectively operable as a hybrid driveline), such electrical coupling facilitates charging the ESS **700** with the ETD **500**. As shown in FIGS. **7**, **11**, **15**, and **16**, the ETD **500** is selectively coupled to the engine **202** by the clutch **300** and through the TAD **400**. Accordingly, the ETD **500** may be selectively driven by the engine **202** when the clutch **300** is engaged. On the other hand, the ETD **500** may be operated using stored energy of the ESS **700** to back-drive the TAD **400** via the accessory drive interface **502** when the clutch **300** is disengaged.

[0043] In some embodiments, the ETD **500** functions as a mechanical conduit or power divider, and transmits the mechanical input received from the engine **202** to the pump system **600** (or other subsystem(s)), the front axle **14**, and/or the rear axle **16**. In some embodiments, the ETD **500** uses the mechanical input to generate electricity for use by the ETD **500** to drive the pump system **600**, the front axle **14**, and/or the rear axle **16**. In some embodiments, the ETD **500** supplements the mechanical input using the stored energy in the ESS **700** to provide an output greater than the input received from the engine **202**. In some embodiments, the ETD **500** uses the mechanical input to generate electricity for storage in the ESS **700**. In some embodiments, the ETD **500** in not configured to generate electricity for storage in the ESS **700** or is prevented from doing so (e.g., for emissions compliance, a dual drive embodiment, etc.) and, instead, the ESS **700** is otherwise charged (e.g., through a charging station, an external input, regenerative braking, etc.).

[0044] According to the exemplary embodiment shown in FIG. **7**, the ETD **500** is configured as an electromechanical infinitely variable transmission ("EMIVT") that includes a first electromagnetic device, shown as a first motor/generator **510**, and a second electromagnetic device, shown as second motor/generator **520**. The first motor/generator **510** and the second motor/generator **520** may be coupled to each other via a plurality of gear sets (e.g., planetary gear sets, etc.). The EMIVT also includes one or more brakes and one or more clutches to facilitate operation of the EMIVT in various modes (e.g., a drive mode, a battery charging mode, a low-range speed mode, a high-range speed mode, a reverse mode, an ultra-low mode, etc.). In some implementations, all of such components may be efficiently packaged in a single housing with only the inputs/outputs thereof exposed.

[0045] By way of example, the first motor/generator **510** may be driven by the engine **202** to generate electricity. The electricity generated by the first motor/generator **510** may be used (i) to charge the ESS **700** and/or (ii) to power the second motor/generator **520** to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or another subsystem coupled thereto. By way of another example, the second motor/generator **520** may be driven by the engine **202** to generate electricity. The electricity generated by the second motor/generator **520** may be used (i) to charge the ESS **700** and/or (ii) to power the first motor/generator **510** to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or another subsystem coupled thereto. By way of another example, the first motor/generator **510** and/or the second motor/generator **520** may be powered by the ESS **700** to (i) back-start the engine **202** (e.g., such that an engine starter is not necessary, etc.), (ii) drive the TAD **400** (e.g., when the engine **202** is off, when the clutch **300** is disengaged, etc.), and/or (iii) drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or another subsystem coupled thereto. By way of yet another example, the first motor/generator **510** may be driven by the engine **202** to generate electricity and the second motor/generator **520** may receive both the generated electricity from the first motor/generator **510** and the stored energy in the ESS **700** to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or another subsystem coupled thereto. By way of yet still another example, the second motor/generator **520** may be driven by the engine **202** to generate electricity and the first motor/generator **510** may receive both the generated electricity from the second motor/generator **520** and the stored energy in the ESS **700** to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or another subsystem coupled thereto. By way of yet still another example, the first motor/generator **510**, the second motor/generator **520**, the plurality of gear sets, the one or more brakes, and/or the one or more clutches may be controlled such that no electricity is generated or consumed by the ETD **500**, but rather the ETD **500** functions as a mechanical conduit or power divider that provides the mechanical input received from the engine **202** to the front axle **14**, the rear axle **16**, the pump system **600**, and/or another subsystem coupled thereto. By way of yet still another example, the ETD **500** may be selectively decoupled from the TAD **400** (e.g., via a clutch of the ETD **500**) such that the engine **202** drives the TAD **400** while the ETD **500** simultaneously uses the stored energy in the ESS **700** to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or another subsystem coupled thereto.

[0046] In some embodiments, the first motor/generator **510** and/or the second motor/generator **520** are controlled to provide regenerative braking capabilities. By way of example, the first motor/generator **510** and/or the second motor/generator **520** may be back-driven by the front axle **14** and/or the rear axle **16** though the axle interface **504** during a braking event. The first motor/generator **510** and/or the second motor/generator **520** may, therefore, operate as a generator that generates electricity during the braking event for storage in the ESS **700** and/or to power electronic components of the vehicle **10**. In other embodiments, the ETD **500** does not provide regenerative braking capabilities.

[0047] Further details regarding the components of the EMIVT and the structure, arrangement, and functionality thereof may be found in (i) U.S. Pat. No. 8,337,352, filed Jun. 22, 2010, (ii) U.S. Pat. No. 9,651,120, filed Feb. 17, 2015, (iii) U.S. Pat. No. 10,421,350, filed Oct. 20, 2015, (iv) U.S. Pat. No. 10,584,775, filed Aug. 31, 2017, (v) U.S. Patent Publication No. 2017/0370446, filed Sep. 7, 2017, (vi) U.S. Pat. No. 10,578,195, filed Oct. 4, 2017, (vii) U.S. Pat. No. 10,982,736, filed Feb. 17, 2019, and (viii) U.S. Pat.

No. 11,137,053, filed Jul. 14, 2020, all of which are incorporated herein by reference in their entireties. In other embodiments, the ETD **500** includes a device or devices different than the EMIVT (e.g., an electronic transmission, a motor and/or generator, a motor and/or generator coupled to a transfer case, an electronic axle, etc.).

Pump System

[0048] As shown in FIGS. **1**, **2**, **4-6**, **8-12**, and **18**, the pump system **600** is coupled to the frame **12** and positioned in a space, shown as gap **40**, between the front cabin **20** and the rear section **30**. In another embodiment, the pump system **600** is otherwise positioned (e.g., within the rear section **30**, etc.). As shown in FIGS. **1**, **2**, **4-6**, **8-12**, and **18**, the pump system **600** includes a frame assembly, shown as pump house **602**, coupled to the frame **12** and a pump assembly, shown as pump **604**, disposed within and supported by the pump house **602**. As shown in FIG. **18**, the pump **604** includes an interface (e.g., an input, etc.), shown as ETD interface **606**, that engages (directly or indirectly) with subsystem interface **506** of the ETD **500**. The ETD **500** may thereby drive the pump **604** to pump a fluid from a source (e.g., an on-vehicle fluid source, an off-vehicle fluid source, an on-board water tank, an on-board agent tank, a fire hydrant, an open body of water, a tanker truck, etc.) to one or more fluid outlets on the vehicle **10** (e.g., a structural discharge, a hose reel, a turret, a high reach extendible turret ("HRET"), etc.).

Energy Storage System

[0049] As shown in FIGS. **1-6**, **8-12**, and **19-26**, the ESS **700** includes a housing, shown as support rack **702**, coupled to the frame **12** and positioned in the gap **40** between the front cabin **20** and the rear section **30**, forward of the pump house **602**; a plurality of battery cells, shown as battery packs **710**, supported by the support rack **702**; an inverter system, shown as inverter assembly **720**, coupled to the frame **12** separate from the support rack **702** and positioned beneath the front cabin **20**; a second cooling assembly, shown as ESS cooling system **730**; a wiring assembly, shown as high voltage wiring assembly **740**; and a charging assembly, shown as high voltage charging system **750**, disposed along a side of the support rack **702**. In another embodiment, the support rack **702** and/or the battery packs **710** are otherwise positioned (e.g., behind the pump house **602**; within the rear section **30**; between frame rails of the frame **12**; to achieve a desired packaging, weight balance, or cost performance of the driveline **100** and the vehicle **10**; etc.).

[0050] As shown in FIGS. **20** and **21**, the support rack **702** includes a plurality of vertical supports, shown as frame members **704**; a plurality of horizontal supports, shown as shelving **706**, coupled to the frame members **704** at various heights along the frame members **704** and that support the battery packs **710**; and a top support, shown as top panel **708**, extending horizontally across a top end of the support rack **702**. As shown in FIGS. **22** and **23**, the inverter assembly **720** includes a bracket, shown as inverter bracket **722**, coupled to one the frame rails of the frame **12** and positioned proximate the support rack **702** (e.g., a front side thereof, etc.) and an inverter, shown as inverter **724**, coupled to and supported by the inverter bracket **722**. In another embodiment, the inverter **724** is located on or coupled directly to the support rack **702**.

[0051] As shown in FIGS. **3**, **19-24**, and **26**, the ESS cooling system **730** includes a heat exchanger, shown as cooling radiator **732**, coupled to an underside of the top panel **708**; a driver, shown as cooling compressor **734**, supported by the shelving **706**; and a plurality of fluid conduits, shown as cooling conduits **736**, fluidly coupling the cooling radiator **732** and the cooling compressor **734** to various components of the driveline **100** including the ETD **500**, the battery packs **710**, the inverter **724**, and/or one or more of the accessories **412**. The ESS cooling system **730** may, therefore, facilitate thermally regulating (i.e., cooling) not only components of the ESS **700**, but also other components of the vehicle **10** (e.g., the ETD **500**, the accessories **412**, etc.).

[0052] As shown in FIG. **3**, the vehicle **10** has an overall height H_1 and the support rack **702** has an overall height H_2 that is greater than H_1 such that at least a portion of the support rack **702** (e.g., the top panel **708**) extends above the front cabin **20**. Such an arrangement causes airflow above the front cabin **20** to flow directly to the cooling radiator **732** to allow for maximum performance of the ESS cooling system **730**. In other embodiments (e.g., embodiments where the battery packs **710** are otherwise located or arranged, etc.), the cooling radiator **732** is otherwise positioned. According to an exemplary embodiment, the ESS cooling system **730** is positioned separate and independent from the engine cooling system **210**. In other embodiments, at least a portion of the ESS cooling system **730** (e.g., the cooling radiator **732**, etc.) is co-located with the engine cooling system **210**. In still other embodiments, one or more components of the ESS cooling system **730** and the engine cooling system **210** are shared (e.g., the engine radiator and the cooling radiator **732** are one in the same, etc.).

[0053] As shown in FIGS. **23-26**, the high voltage wiring assembly **740** includes a plurality of high voltage wires, shown as high voltage wires **742**, electrically connecting various electrically-operated components of the vehicle **10** to the battery packs **710**. Specifically, as shown in FIGS. **23-25**, the battery packs **710** are electrically connected to the ETD **500**, the inverter **724**, and the high voltage charging system **750** by the high voltage wires **742**. The battery packs **710** may be charged by an external source (e.g., a high voltage power source, etc.) via the high voltage charging system **750** (e.g., via a port thereof, etc.). According to an exemplary embodiment, the ETD **500** draws stored energy in the battery packs **710** via the high voltage wires **742** to facilitate operation thereof. In some embodiments, the ETD **500** does not charge the battery packs **710** with energy generated thereby. In other embodiments, the ETD **500** is operable to charge the battery packs **710** with the energy generated thereby. It should be understood that the battery packs **710** may power additional components of the vehicle **10** (e.g., lights, sirens, communication systems, displays, electric accessories, electric motors, etc.).

Look and Feel

[0054] According to an exemplary embodiment, the components of the driveline **100** have been integrated into the vehicle **10** in such a way that the vehicle **10** looks, feels, and operates as if it were a traditional, internal combustion engine only driven vehicle. The current approach in the market relating to the electrification of fire fighting vehicles

has been to re-design the vehicle entirely to accommodate the electrification components such that the resultant vehicles look substantially different from and are controlled differently from their internal combustion engine driven predecessors. Applicant has identified, however, that consumers, specifically fire fighters, are interested in adding electrified vehicles to their fleets, but they want the vehicles to remain the same as their predecessors in terms of component layout, compartment locations, operations, and aesthetic appearance. Accordingly, Applicant has engaged in an extensive research and development process to design and package the electrified components onto the vehicle **10**, with only minor changes relative to its internal combustion engine driven predecessors. Doing so provides various advantages, including vehicle operators do not have to be retrained on how to operate a completely new vehicle, technicians know exactly where the driveline components are located, equipment from a decommissioned vehicle can easily be transferred to an identical position on the new, electrified vehicle, etc., all which allow for easy transition and acceptance by the end users, eliminates training, and allows for increased uptime of the vehicle **10**.

[0055] Specifically, the vehicle **10**, according to the exemplary embodiment shown in FIGS. **1-6**, looks identical to its internal combustion engine driven predecessor, except for the addition of the support rack **702** and the components supported thereby. The pump house **602** and the engine **202** remain in their usual position, the ETD **500** is in the position where a traditional mechanical transmission would be located, the front cabin **20** and the rear section **30** maintain their typical structure, control layout, compartment layout, etc. However, because of the addition of the ESS **700** to electrify the vehicle **10**, the overall length L_1 of the vehicle **10** was extended by a length L_2 to accommodate the addition of the support rack **702** and the components supported thereby (e.g., the battery packs **710**, the cooling radiator **732**, the cooling compressor **734**, etc.). According to an exemplary embodiment, the length L_2 is 20 inches or less (e.g., 20, 18, 16, 12, etc. inches). However, as described herein, in some embodiments, the battery packs **710** are otherwise positioned and, therefore, the support rack **702** may be eliminated. In such embodiments, the vehicle **10** would appear to be identical to its internal combustion engine driven predecessor to an unknowing party.

[0056] According to an exemplary embodiment, in addition to the overall look of the vehicle **10**, the operator controls have been kept as similar to its internal combustion engine driven predecessor such that vehicle starting, vehicle driving, and pumping operations are identical such that the operator has no indication that the vehicle **10** is different (i.e., electrified) and, therefore, eliminates any need for training to get an already experienced operator into a position to drive and operate the vehicle **10** and the components thereof. As shown in FIGS. **27** and **28**, the user interface **820** within the front cabin **20** of the vehicle **10** includes a plurality of buttons, dials, switches, etc. that facilitate engaging and operating the driveline **100**. Specifically, the user interface **820** includes a first input (e.g., a rotary switch, etc.), shown as battery isolation switch **822**, a second input (e.g., a button, a switch, etc.), shown as ignition switch **824**, a third input (e.g., a button, a switch, etc.), shown as start switch **826**, and a fourth input (e.g., a button, a switch, etc.), shown as pump switch **828**. The battery isolation switch **822** can be engaged (e.g., turned, etc.) to allow stored energy within the ESS **700** to be accessed. The ignition switch **824** can then be engaged (e.g., pressed, flipped, etc.) to make low voltage and high voltage contacts engage to activate various electric components of the vehicle **10** (e.g., the front cabin **20** comes to life, the components required to start the engine **202** are activated, etc.). The start switch **826** activates the engine **202** and/or the ETD **500** of the driveline **100** (e.g., based on a mode of operation, based on the current location of the vehicle **10**, etc.) that facilitate driving the vehicle **10** and the subsystems thereof (e.g., the pump system **600**, the TAD **400**, the aerial ladder assembly, etc.). The pump switch **828** (or other subcomponent switch) can then be engaged (e.g., pressed, flipped, etc.) to start the operation thereof (e.g., drive the pump **604** via the ETD **500**, drive the aerial ladder assembly via the ETD **500**, etc.).

Control System

[0057] According to the exemplary embodiment shown in FIG. **29**, a control system **800** for the vehicle **10** includes a controller **810**. In one embodiment, the controller **810** is configured to selectively engage, selectively disengage, control, or otherwise communicate with components of the vehicle **10**. As shown in FIG. **29**, the controller **810** is coupled to (e.g., communicably coupled to) components of the driveline **100** (e.g., the engine system **200**; the clutch **300**; the ETD **500**; subsystems including the pump system **600** and/or the second subsystem **610** such as, for example, an aerial ladder assembly or another subsystem; the ESS **700**; etc.), the user interface **820**, a first external system, shown as telematics system **840**, a second external system, shown as global positioning system ("GPS") **850**, and one or more sensors, shown as sensors **860**. By way of example, the controller **810** may send and receive signals (e.g., control signals) with the components of the driveline **100**, the user interface **820**, the telematics system **840**, the GPS system **850**, and/or the sensors **860**.

[0058] The controller **810** may be implemented as a general-purpose processor, an application specific integrated circuit ("ASIC"), one or more field programmable gate arrays ("FPGAs"), a digital-signal-processor ("DSP"), circuits containing one or more processing components, circuitry for supporting a microprocessor, a group of processing components, or other suitable electronic processing components. According to the exemplary embodiment shown in FIG. **29**, the controller **810** includes a processing circuit **812** and a memory **814**. The processing circuit **812** may include an ASIC, one or more FPGAs, a DSP, circuits containing one or more processing components, circuitry for supporting a microprocessor, a group of processing components, or other suitable electronic processing components. In some embodiments, the processing circuit **812** is configured to execute computer code stored in the memory **814** to facilitate the activities described herein. The memory **814** may be any volatile or non-volatile computer-readable storage medium capable of storing data or computer code relating to the activities described herein. According to an exemplary embodiment, the memory **814** includes computer code modules (e.g., executable code, object code, source code, script code, machine code, etc.) configured for execution by the processing circuit **812**. In some embodiments, the controller **810** may represent a collection of processing devices. In such cases, the processing circuit **812** represents the collective processors of the devices, and the memory **814** represents the collective storage devices of the devices.

[0059] The user interface **820** includes a display and an operator input, according to one embodiment. The display may be configured to display a graphical user interface, an image, an icon, or still other information. In one embodiment, the display includes a graphical user interface configured to provide general information about the vehicle **10** (e.g., vehicle speed, fuel level, battery level, pump performance/status, aerial ladder information, warning lights, agent levels, water levels, etc.). The graphical user interface may also be configured to display a current mode of operation, various potential modes of operation, or still other information relating to the vehicle **10** and/or the driveline **100**. By way of example, the graphical user interface may be configured to provide specific information regarding the operation of the driveline **100** (e.g., whether the clutch **300** is engaged, whether the engine **202** is on, whether the pump **604** is in operation, etc.).

[0060] The operator input may be used by an operator to provide commands to the components of the vehicle **10**, the driveline **100**, and/or still other components or systems of the vehicle **10**. As shown in FIG. **29**, the operator input includes the battery isolation switch **822**, the ignition switch **824**, the start switch **826**, and the pump switch **828**. The operator input may include one or more additional buttons, knobs, touchscreens, switches, levers, joysticks, pedals, or handles. In some instances, an operator may be able to press a button and/or otherwise interface with the operator input to command the controller **810** to change a mode of operation for the driveline **100**. The operator may be able to manually control some or all aspects of the operation of the driveline **100** and/or other components of the vehicle **10** using the display and the operator input. It should be understood that any type of display or input controls may be implemented with the systems and methods described herein.

[0061] The telematics system **840** may be a server-based system that monitors various telematics information and provides telematics data based on the telematics information to the controller **810** of the vehicle **10**. The GPS system **850** may similarly be a server-based system that monitors various GPS information and provides GPS data based on the GPS information to the controller **810** of the vehicle **10**. The telematics data may include an indication that the vehicle **10** is being dispatched to a scene. The telematics data may additionally or alternatively include details regarding the scene such as the location of the scene, characteristics of the scene (e.g., the type of fire, the current situation, etc.), and the like. The GPS data may include an indication of a current location of the vehicle **10**. The GPS data and/or the telematics data may additionally or alternatively include route details between the current location of the vehicle **10** and the location of the scene such as route directions, emissions regulations along the route, noise restrictions along the route, a proximity of the vehicle **10** to a predetermined geofence (e.g., a roll-out geofence, a roll-in geofence, a noise restriction geofence, an emissions limiting geofence, etc.), and the like. Such telematics data and/or GPS data may be utilized by the controller **810** to perform one or more functions described herein.

[0062] In some embodiments, the telematics system **840** and the GPS system **850** are integrated into a single system. In some embodiments, the controller **810** is configured to function as an intermediary between the telematics system **840** and the GPS system **850**. By way of example, the controller **810** may receive the telematics data from the telematics system **840** when the vehicle **10** is assigned to be dispatched to a scene and, then, the controller **810** may use the telematics data to acquire the GPS data from the GPS system **850**. In some embodiments, the telematics system **840** and the GPS system **850** are configured to communicate directly with each other (e.g., the GPS system **850** may acquire scene location information from the telematics system **840** to provide the GPS data to the controller **810**, etc.) such that the controller **810** does not need to function as an intermediary. The controller **810** may receive or acquire the telematics data and/or the GPS data from the telematics system **840** and/or GPS system **850** on a periodic basis, automatically, upon request, and/or in another suitable way.

[0063] The sensors **860** may include one or more sensors that are configured to acquire sensor data to facilitate monitoring operational parameters/characteristics of the components of the driveline **100** with the controller **810**. By way of example, the sensors **860** may include one or more engine sensors (e.g., a speed sensor, an exhaust gas sensor, a NO_x sensor, an O_2 sensor, etc.) that are configured to facilitate monitoring operational parameters/characteristics of the engine system **200** (e.g., engine speed, exhaust gas composition, NO_x levels, O_2 levels, etc.). By way of another example, the sensors **860** may additionally or alternatively include one or more ETD sensors (e.g., speed sensors, voltage sensors, current sensors, etc.) that are configured to facilitate monitoring operational parameters/characteristics of the ETD **500** (e.g., input speed; output speed; voltage, current, and/or power of incoming power from the ESS **700**; voltage, current, and/or power generated by the ETD **500**; etc.). By way of still another example, the sensors **860** may additionally or alternatively include one or more subsystem sensors (e.g., speed sensors, flow rate sensors, pressure sensors, water level sensors, agent level sensors, position sensors, etc.) that are configured to facilitate monitoring operational parameters/characteristics of the pump system **600** (e.g., pump speed, output fluid flow rate, output fluid pressure, water level, agent level, etc.) and/or the second subsystem **610** (e.g., aerial ladder rotational position, aerial ladder horizontal length, aerial ladder vertical height, etc.). By way of still another example, the sensors **860** may additionally or alternatively include one or more ESS sensors (e.g., voltage sensors, current sensors, state-of-charge ("SOC") sensors, etc.) that are configured to facilitate monitoring operational parameters/characteristics of the ESS **700** (e.g., voltage, current, and/or power of incoming power from the ETD **500** and/or the high voltage charging system **750**; voltage, current, and/or power being output to the electrically-operated components of the vehicle **10**; a SOC of the ESS **700**; etc.). In some embodiments, the controller **810** is configured to automatically change a mode of operation for the driveline **100** and/or recommend to an operator via the user interface **820** to approve a change to the mode of operation of the driveline **100** based on the telematics data, the GPS data, and/or the sensor data.

Operational Modes

[0064] As a general overview, the controller **810** is configured to operate the driveline **100** in various operational modes. In some embodiments, the controller **810** is configure to generate control signals for one or more components of the driveline **100** to transition the driveline **100** between the various operational modes in response to receiving a user input, a command, a request, etc. from the user interface

820. In some embodiments, the controller **810** is configure to generate control signals for one or more components of the driveline **100** to transition the driveline **100** between the various operational modes based on the telematics data, the GPS data, and/or the sensor data. The various operational modes of the driveline **100** may include a pure engine mode, a pure electric mode, a charging mode, an electric generation drive mode, a boost mode, a distributed drive mode, a roll-out mode, a roll-in mode, a stop-start mode, a location tracking mode, a scene mode, a pump-and-roll mode, and/or still other modes. In some embodiments, two or more modes may be active simultaneously. In some embodiments (e.g., in embodiments where the driveline **100** is a "dual drive" driveline that is not operable as a "hybrid" driveline, etc.), the driveline **100** is not operable in the charging mode of operation.

Pure Engine Mode

[0065] The controller **810** may be configured to operate the vehicle **10** in a pure engine mode of operation. To initiate the pure engine mode of operation, the controller **810** is configured to engage the clutch **300** to couple (i) the engine **202** to the TAD **400** and (ii) the engine **202** to the ETD **500**. The engine **202** may, therefore, provide a mechanical output (e.g., based on a control signal from the controller **810**, based on an input received from an accelerator pedal, etc.) to the TAD **400** to operate the accessories **412** and/or the ETD **500**. During the pure engine mode of operation, the controller **810** is configured to control the ETD **500** such that the ETD **500** functions as a mechanical conduit or power divider between (i) the engine **202** and (ii) one or more other components of the driveline **100** including (a) the front axle **14** and/or the rear axle **16** and/or (b) the vehicle subsystem (s) including the pump system **600** and/or the second subsystem **610** (e.g., an aerial ladder assembly, etc.). In some embodiments, the ETD **500** is not configured to generate electricity based on a mechanical input received from the engine **202**. In some embodiments, the ETD **500** is configured to generate electricity based on a mechanical input received from the engine **202**, however, the controller **810** is configured to control the ETD **500** such that the ETD **500** does not generate electricity (e.g., for storage in the ESS **700**, for use by the ETD **500**, etc.) during the pure engine mode of operation.

[0066] In some embodiments, the controller **810** is configured to implement the pure engine mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the pure engine mode of operation in response to the SOC of the ESS **700** reaching or falling below a SOC threshold. In one embodiment, the SOC threshold is determined based on an amount of stored energy needed to perform one or more of the other modes of operation along the route of the vehicle **10** (e.g., the roll-out mode, the roll-in mode, the location tracking mode, etc.). In another embodiment, the SOC threshold is manufacturer or owner set (e.g., 10%, 20%, 25%, 30%, 40%, etc.). In some embodiments, the controller **810** is configured to prevent the pure engine mode of operation from being engaged (e.g., when the vehicle **10** is within a roll-out geofence, when the vehicle **10** is within a roll-in geofence, when the vehicle **10** is within a noise restriction geofence, when the vehicle **10** is within an emissions limiting geofence, regardless of the SOC of the ESS **700**, etc.).

Pure Electric Mode

[0067] The controller **810** may be configured to operate the vehicle **10** in a pure electric mode of operation. To initiate the pure electric mode of operation, the controller **810** is configured to (i) turn off the engine **202** (if the engine **202** is on) and (ii) disengage the clutch **300** (if the clutch **300** is engaged) to decouple the engine **202** from the remainder of the driveline **100** (e.g., the TAD **400**, the ETD **500**, etc.). During the pure electric mode of operation, the ETD **500** is configured to draw and use power from the ESS **700** to provide a mechanical output (e.g., based on a control signal from the controller **810**, based on an input received from an accelerator pedal, etc.) to (i) the TAD **400** to operate the accessories **412** and/or (ii) one or more other components of the driveline **100** including (a) the front axle **14** and/or the rear axle **16** and/or (b) the vehicle subsystem(s) including the pump system **600** and/or the second subsystem **610** (e.g., an aerial ladder assembly, etc.).

[0068] In some embodiments, the controller **810** is configured to implement the pure electric mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the pure electric mode of operation in response to the SOC of the ESS **700** being above the SOC threshold (e.g., to provide increased fuel efficiency, to reduce noise pollution, etc.). In one embodiment, the SOC threshold is determined based on an amount of stored energy needed to perform one or more of the other modes of operation along the route of the vehicle **10** (e.g., the roll-out mode, the roll-in mode, the location tracking mode, etc.). In some embodiments, the controller **810** is configured to implement the pure electric mode of operation regardless of the SOC of the ESS **700** (e.g., when the vehicle **10** is within a roll-out geofence, when the vehicle **10** is within a roll-in geofence, when the vehicle **10** is within a noise restriction geofence, when the vehicle **10** is within an emissions limiting geofence, etc.).

Charging Mode

[0069] The controller **810** may be configured to operate the vehicle **10** in a charging mode of operation. To initiate the charging mode of operation, the controller **810** is configured to engage the clutch **300** to couple (i) the engine **202** to the TAD **400** and (ii) the engine **202** to the ETD **500**. The engine **202** may, therefore, provide a mechanical output (e.g., based on a control signal from the controller **810**, based on an input received from an accelerator pedal, etc.) to the TAD **400** to operate the accessories **412** and/or the ETD **500**. During the charging mode of operation, the controller **810** is configured to control the ETD **500** such that the ETD **500** functions at least partially as a generator. Specifically, the engine **202** provides a mechanical input to the ETD **500** and the ETD **500** converts the mechanical input into electricity. The ETD **500** may be configured to provide the generated electricity to the ESS **700** to charge the ESS **700** and, optionally, (i) provide the generated electricity to power one or more electrically-operated accessories or components of the vehicle **10** and/or (ii) use the generated electricity to operate the ETD **500** at least partially as a motor to drive one or more component of the driveline **100** including the front axle **14**, the rear axle **16**, the pump system **600**, and/or the second subsystem **610**.

[0070] In some embodiments, the controller **810** is configured to implement the charging mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the charging mode of operation in response to the SOC of the ESS **700** being below the SOC threshold. In some embodiments, the controller **810** is configured to implement the charging mode of operation only when the vehicle **10** is stationary and/or parked (e.g., at a scene, at the fire house, etc.). In such embodiments, the ETD **500** may not function as a motor during the charging mode of operation. Alternatively, the ETD **500** may function as a motor during the charging mode of operation to drive the subsystems (e.g., the pump system **600**, the second subsystem **610**, etc.).

Electric Generation Drive Mode

[0071] The controller **810** may be configured to operate the vehicle **10** in an electric generation drive mode of operation. In the electric generation drive mode of operation, (i) the engine **202** is configured to consume fuel from a fuel tank to drive one or more components of the driveline **100** and (ii) the ETD **500** is configured to generate electricity to drive one or more components of the driveline **100**. To initiate the electric generation drive mode of operation, the controller **810** is configured to engage the clutch **300** to couple (i) the engine **202** to the TAD **400** and (ii) the engine **202** to the ETD **500**. During the electric generation drive mode, (i) the engine **202** drives the TAD **400** and the ETD **500** through the clutch **300** using fuel and (ii) the ETD **500** (a) generates electricity based on the mechanical input from the engine **202** and (b) uses the generated electricity to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or the second subsystem **610**.

[0072] In some embodiments, the controller **810** is configured to implement the electric generation drive mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the electric generation drive mode of operation in response to the SOC of the ESS **700** being below the SOC threshold.

Boost Mode

[0073] The controller **810** may be configured to operate the vehicle **10** in a boost mode of operation. To initiate the boost mode of operation, the controller **810** is configured to engage the clutch **300** to couple (i) the engine **202** to the TAD **400** and (ii) the engine **202** to the ETD **500**. During the boost mode, (i) the engine **202** drives the TAD **400** and the ETD **500** through the clutch **300** using fuel and (ii) the ETD **500** (a) generates electricity based on the mechanical input from the engine **202** and (b) uses the generated electricity and the stored energy in the ESS **700** to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or the second subsystem **610**. Such combined energy generation and energy draw facilitates "boosting" the output capabilities of the ETD **500**.

[0074] In some embodiments, the controller **810** is configured to implement the boost mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the boost mode of operation in response to a need for additional output from the ETD **500** (and if there is sufficient SOC in the ESS **700**) to drive the front axle **14**, the rear axle **16**, the pump system **600**, and/or the second subsystem **610**.

Distributed Drive Mode

[0075] In some embodiments, the ETD **500** includes an ETD clutch that facilitates decoupling the ETD **500** from the TAD **400** and, therefore, decoupling the ETD **500** from the engine **202** when the clutch **300** is engaged. In such embodiments, the controller **810** may be configured to operate the vehicle **10** in a distributed drive mode of operation. To initiate the distributed drive mode of operation, the controller **810** is configured to engage the clutch **300** to couple the engine **202** to the TAD **400** and disengage the ETD clutch to disengage the ETD **500** from the engine **202** and the TAD **400**. During the distributed drive mode, (i) the engine **202** drives the TAD **400** through the clutch **300** using fuel and (ii) the ETD **500** drives the front axle **14**, the rear axle **16**, the pump system **600**, and/or the second subsystem **610** using stored energy in the ESS **700**.

[0076] In some embodiments, the controller **810** is configured to implement the distributed drive mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the distributed drive mode of operation to reduce a load on the engine **202** and/or the ETD **500** by distributing component driving responsibilities.

Roll-Out Mode

[0077] The controller **810** may be configured to operate the vehicle **10** in a roll-out mode of operation. For the roll-out mode of operation, the controller **810** is configured to operate the driveline **100** similar to the pure electric mode of operation. More specifically, the controller **810** is configured to start the vehicle **10** and operate the components of the driveline **100** (e.g., the TAD **400**, the front axle **14**, the rear axle **16**, the pump system **600**, the second subsystem **610**, etc.) with the ETD **500** while the engine **202** is off until a roll-out condition it met. Once the roll-out condition is met, the controller **810** is configured to transition the driveline **100** to the pure electric mode, the pure engine mode, the charging mode, the electric generation drive mode, the boost mode, the distributed drive mode, the scene mode, or still another suitable mode depending on the current state of the vehicle **10** (e.g., SOC of the ESS **700**, etc.) and/or the location of the vehicle **10** (e.g., en route to the scene, at the scene, in a noise reduction zone, in an emission free/reduction zone, etc.). The roll-out condition may be or include (i) the vehicle **10** traveling a predetermined distance or being outside of a roll-out geofence (e.g., indicated by the telematics data, the GPS data, etc.), (ii) the vehicle **10** reaching a certain speed, (iii) the vehicle **10** reaching a certain location (e.g., a scene, etc.; indicated by the telematics data, the GPS data, etc.), (iv) the vehicle **10** being driven for a period of time, (v) the SOC of the ESS **700** reaching or falling below the SOC threshold, and/or (vi) the operator selecting a different mode of operation. The roll-out mode of operation may facilitate preventing combustion emissions of the engine **202** filling the fire station, hanger, or other indoor or ventilation-limited location where the vehicle **10** may be located upon startup and take-off. For example, when in the roll-out mode of operation, the vehicle

10 may begin transportation to the scene without requiring startup of the engine **202**. The engine **202** may then be started after the vehicle **10** has already begun transportation to the scene (if necessary).

[0078] In some embodiments, the controller **810** is configured to implement the roll-out mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the roll-out mode of operation in response to the telematics data and/or the GPS data indicating that (i) the vehicle **10** has been selected to respond to a scene and/or (ii) the vehicle **10** is inside of a roll-out geofence (e.g., inside or proximate a fire station, a hanger, another vehicle storage location that is indoors, a location with limited ventilation, etc.). In some embodiments, the controller **810** is configured to implement the roll-out mode of operation regardless of the SOC of the ESS **700**, so long as the SOC of the ESS **700** is sufficient to complete the roll-out operation (e.g., which may be to simply drive out of the fire house or other minimal distance). In some embodiments, the controller **810** is configured to implement the roll-out mode only if the SOC of the ESS **700** is above a first SOC threshold and maintain operating the driveline **100** in the pure electric mode of the operation until the SOC of the ESS **700** reaches or falls below a second SOC threshold that is different than (e.g., greater than, less than, etc.) the first SOC threshold. By way of example, the first SOC threshold may be 40% and the second SOC threshold may be 20%.

Roll-In Mode

[0079] The controller **810** may be configured to operate the vehicle **10** in a roll-in mode of operation. For the roll-in mode of operation, the controller **810** is configured to operate the driveline **100** similar to the pure electric mode of operation. More specifically, the controller **810** is configured to turn off the engine **202** (if already on) and operate the components of the driveline **100** (e.g., the TAD **400**, the front axle **14**, the rear axle **16**, the pump system **600**, the second subsystem **610**, etc.) with the ETD **500** while the engine **202** is off when a roll-in condition is present. When the roll-in condition is present, the controller **810** is configured to transition the driveline **100** from whatever mode the driveline **100** is currently operating in to the roll-in mode. The roll-in condition may be or include (i) the vehicle **10** entering a roll-in geofence (e.g., indicated by the telematics data, the GPS data, etc.), (ii) the vehicle **10** reaching a certain location (e.g., a fire house, a hanger, a location where the vehicle **10** is indoors or where ventilation to the outside is limited, etc.; indicated by the telematics data, the GPS data, etc.), and/or (iii) the operator selecting the roll-in mode of operation. The roll-in mode of operation may facilitate preventing combustion emissions of the engine **202** filling the fire station or other location where ventilation may be limited.

[0080] In some embodiments, the controller **810** is configured to implement the roll-in mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the roll-in mode of operation in response to the telematics data and/or the GPS data indicating that the vehicle **10** is inside of a roll-in geofence (e.g., inside or proximate a fire station, a hanger, another vehicle storage location that is indoors, a location with limited ventilation, etc.). In some embodiments, the controller **810** is configured to implement the roll-in mode of operation regardless of the SOC of the ESS **700**, so long as the SOC of the ESS **700** is sufficient to complete the roll-in operation (e.g., which may be to simply drive into the fire house or other minimal distance).

Location Tracking Mode

[0081] The controller **810** may be configured to operate the vehicle **10** in a location tracking mode of operation. For the location tracking mode of operation, the controller **810** is configured to (i) monitor the telematics data and/or the GPS data as the vehicle **10** is driving and (ii) switch the driveline **100** between (a) a first mode of operation where the engine **202** is used (e.g., the pure engine mode of operation, the electric generation drive mode of operation, the charging mode of operation, the boost mode of operation, the distributed drive mode of operation, etc.) and (b) a second mode of operation where the engine **202** is not used (e.g., the pure electric mode of operation, the roll-out mode of operation, the roll-in mode of operation, etc.) based on the telematics data and/or the GPS data.

[0082] By way of example, the GPS data and/or the telematics data may include route details (i) between the current location of the vehicle **10** and a location ahead of the vehicle **10** or (ii) along a planned route of the vehicle **10**. The route details may indicate emissions regulations and/or noise restriction information ahead of the vehicle **10** and/or along the planned route of the vehicle **10**. The controller **810** may, therefore, be configured to monitor the location of the vehicle **10** and transition the driveline **100** from the first mode of operation where the engine **202** is used to the second mode of operation where the engine **202** is not used in response to the vehicle **10** approaching and/or entering an emission-restricted and/or noise-restricted zone (e.g., a roll-out geofence, a roll-in geofence, a noise restriction geofence, an emissions limiting geofence, etc.) to reduce or eliminate emissions and/or noise pollution emitted from the vehicle **10** due to operation of the engine **202**. The controller **810** may then be configured to transition the driveline **100** back to the first mode of operation where the engine **202** is used after leaving the emission-restricted and/or noise-restricted zone. During the location tracking mode of operation, the controller **810** may, therefore, forecast future electric consumption needs and manage the SOC of the ESS **700** to ensure enough SOC is saved or regenerated to accommodate the electric consumption needs of the vehicle **10** along the route.

[0083] In some embodiments, the controller **810** is configured to implement the location tracking mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the location tracking mode of operation each time the vehicle **10** is turned on (e.g., if approved by the owner, etc.).

Stop-Start Mode

[0084] The controller **810** may be configured to operate the vehicle **10** in a stop-start mode of operation. For the stop-start mode of operation, the controller **810** is configured to transition the driveline **100** between (i) a first mode of operation where the engine **202** is used (e.g., the pure engine mode of operation, the electric generation drive mode of operation, the charging mode of operation, the boost mode of operation, the distributed drive mode of operation, etc.)

and (ii) a second mode of operation where the engine **202** is not used (e.g., the pure electric mode of operation, etc.) in response to a stopping event. By way of example, the controller **810** may be configured to monitor for stopping events and then, if the vehicle **10** stays stationary for more than a time threshold (e.g., one, two, three, four, etc. seconds), turn off the engine **202** if the driveline **100** is currently operating in the first mode of operation where the engine **202** is used. The controller **810** may then be configured to initiate the second mode of operation where the engine **202** is not used (e.g., the pure electric mode of the operation, etc.) for the subsequent take-off (e.g., in response to an accelerator pedal input, etc.). The controller **810** may be configured to transition the driveline **100** back to the first mode of operation in response to a transition condition. The transition condition may be or include (i) the vehicle **10** traveling a predetermined distance, (ii) the vehicle **10** reaching a certain speed, (iii) the vehicle **10** being driven for a period of time, (iv) the SOC of the ESS **700** reaching or falling below the SOC threshold, and/or (v) the operator selecting the first mode of operation.

[0085] In some embodiments, the controller **810** is configured to implement the stop-start mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820**. In some embodiments, the controller **810** is configured to implement the stop-start mode of operation each time the vehicle **10** is turned on (e.g., if approved by the owner, etc.). In some embodiments, the controller **810** is configured to implement the stop-start mode of operation only if the SOC of the ESS **700** is above the SOC threshold.

Scene Mode

[0086] The controller **810** may be configured to operate the vehicle **10** in a scene mode of operation. For the scene mode of operation, the controller **810** is configured to control the ETD **500** to drive the subsystems including the pump system **600** and/or the second subsystem **610**. In one embodiment, the controller **810** is configured to operate the driveline **100** in the pure engine mode of operation to provide the scene mode of operation. In some embodiments, the pure engine mode of operation is used regardless of the level of SOC of the ESS **700**. In another embodiment, the controller **810** is configured to operate the driveline **100** in the pure electric mode of operation to provide the scene mode of operation. In such an embodiment, the use of the pure electric mode may be dependent upon the SOC of the ESS **700** being above a SOC threshold. In other embodiments, the controller **810** is configured to operate the driveline **100** in the electric generation drive mode of operation, the boost mode of operation, the distributed drive mode of operation, or the charging mode of operation to provide the scene mode of operation.

[0087] In some embodiments, the controller **810** is configured to implement the scene mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820** (e.g., to engage the pump system **600**, the second subsystem **610**, etc.). In some embodiments, the controller **810** is configured to implement the scene mode of operation automatically upon detecting that the vehicle **10** arrived at the scene (e.g., based on the GPS data, etc.). In some embodiments, the controller **810** is configured to implement the scene mode of operation only if the vehicle **10** is in a park state. When leaving the scene, the controller **810** may be configured to implement the roll-out mode of operation, the pure electric mode of operation, the pure engine mode of operation, the electric generation drive mode of operation, the boost mode of operation, the distributed drive mode of operation, or the charging mode of operation dependent upon operational needs along the route back to the station and/or the current state of the vehicle **10** (e.g., the SOC of the ESS **700**, roll-in requirements, noise restrictions, emissions restrictions, etc.).

Pump-and-Roll Mode

[0088] The controller **810** may be configured to operate the vehicle **10** in a pump-and-roll mode of operation. For the pump-and-roll mode of operation, the controller **810** is configured to control the ETD **500** to (i) drive the subsystems including the pump system **600** and/or the second subsystem **610** and (ii) the front axle **14** and/or the rear axle **16**, simultaneously. In one embodiment, the controller **810** is configured to operate the driveline **100** in the pure engine mode of operation to provide the pump-and-roll mode of operation. In some embodiments, the pure engine mode of operation is used regardless of the level of SOC of the ESS **700**. In another embodiment, the controller **810** is configured to operate the driveline **100** in the pure electric mode of operation to provide the pump-and-roll mode of operation. In such an embodiment, the use of the pure electric mode may be dependent upon the SOC of the ESS **700** being above a SOC threshold. In other embodiments, the controller **810** is configured to operate the driveline **100** in the electric generation drive mode of operation, the boost mode of operation, the distributed drive mode of operation, or the charging mode of operation to provide the pump-and-roll mode of operation. In some embodiments, the controller **810** is configured to implement the pump-and-roll mode of operation in response to a request from the operator of the vehicle **10** via the user interface **820** (e.g., to engage the pump system **600** and/or the second subsystem **610** while driving the vehicle **10**, an accelerator pedal input while pumping, etc.).

Transition Between Electric Drive and Engine Drive Operations

[0089] The controller **810** may be configured to operate the vehicle **10** to seamlessly transition between (i) a first mode of operation where the engine **202** is not providing an input to the ETD **500** (e.g., the pure electric mode, the distributed drive mode, etc.) and (ii) a second mode of operation where the engine **202** is providing an input to the ETD **500** (e.g., the pure engine mode, the charging mode, the electric generation drive mode, the boost mode, etc.). Specifically, the controller **810** may be configured to control the mode transition to provide seamless power delivery, whether to the ground (e.g., the front axle **14** and/or the rear axle **16**) or to PTO driven components (e.g., the pump system **600**, the second subsystem **610**, the aerial ladder assembly, etc.) to allow continuous, uninterrupted operation. The ability to seamlessly transition modes on the vehicle **10** is particularly important to meet the operational mission profile that such a vehicle is expected to deliver.

[0090] By way of example, the controller **810** may be configured transition from the first mode of operation (i.e., where no input is provided by the engine **202** to the ETD **500**) to the second mode of operation (i.e., where an input

is provided by the engine **202** to the ETD **500**), or vice versa, in response to a transition condition. As described above, the transition condition(s) may be or include the SOC of the ESS **700** reaching a minimum SOC threshold, an operator transition command, a roll-out geofence, a roll-in geofence, an emissions limiting geofence, a noise restriction geofence, and/or still other conditions. In response to the transition condition and to provide seamless transition from the first mode to the second mode, the controller **810** may be configured to (i) start the engine **202** (if off), (ii) adjust the speed of the engine **202** to match the speed of the ETD **500** at the input thereof, and (iii) once the speed is matched, engage the clutch **300** to couple the engine **202** to the ETD **500**. In embodiments where the ETD **500** includes the ETD clutch, the controller **810** may be configured to engage the clutch **300** (if not already engaged) and the ETD clutch when the speed is matched. In some embodiments (e.g., embodiments where the ETD **500** does not charge the ESS **700** based on the mechanical input received from the engine **202**), at the moment when the clutch **300** and/or the ETD clutch are engaged, the controller **810** may be configured to control the ETD **500** to prevent energy from being transferred to the ESS **700** (if the ETD **500** is being operated to generate electricity in the second mode). In some embodiments, the controller **810** is configured to physically disconnect the ESS **700** from the ETD **500** (e.g., by opening ESS contactors) to provide a physical barrier between the ESS **700** and the ETD **500**. However, such physical disconnection would prevent charging the ESS **700** with the ETD **500** during a regenerative braking event.

[0091] As utilized herein, the terms "approximately," "about," "substantially", and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.

[0092] It should be noted that the term "exemplary" and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0093] The term "coupled" and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If "coupled" or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of "coupled" provided above is modified by the plain language meaning of the additional term (e.g., "directly coupled" means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of "coupled" provided above. Such coupling may be mechanical, electrical, or fluidic.

[0094] References herein to the positions of elements (e.g., "top," "bottom," "above," "below") are merely used to describe the orientation of various elements in the figures. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

[0095] The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some embodiments, particular processes and methods may be performed by circuitry that is specific to a given function. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is communicably connected to the processor via a processing circuit and includes computer code for executing (e.g., by the processing circuit or the processor) the one or more processes described herein.

[0096] The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, or other optical disk storage, magnetic disk storage or other magnetic stor-

age devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0097] Although the figures and description may illustrate a specific order of method steps, the order of such steps may differ from what is depicted and described, unless specified differently above. Also, two or more steps may be performed concurrently or with partial concurrence, unless specified differently above. Such variation may depend, for example, on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations of the described methods could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps, and decision steps.

[0098] It is important to note that the construction and arrangement of the vehicle **10** and the systems and components thereof as shown in the various exemplary embodiments is illustrative only. Additionally, any element disclosed in one embodiment may be incorporated or utilized with any other embodiment disclosed herein.

1. An electrified fire fighting vehicle comprising:
- a chassis;
- a cab coupled to the chassis;
- a body coupled to the chassis;
- a pump system; and
- a driveline including:
  - a front axle coupled to the chassis;
  - a rear axle coupled to the chassis;
  - an energy storage system;
  - an engine coupled to the chassis; and
  - an electromechanical device coupled to the chassis, the engine, and at least one of the front axle or the rear axle;
- wherein the driveline is a dual drive driveline such that, during any and all modes of operation of the driveline, the electromechanical device is incapable of or prevented from charging the energy storage system at any time when driven by the engine.

2. The electrified fire fighting vehicle of claim **1**, wherein the electromechanical device is configured to provide regenerative braking capabilities and generate electricity for storage in the energy storage system during a regenerative braking event to charge the energy storage system.

3. The electrified fire fighting vehicle of claim **1**, wherein the electromechanical device includes a motor/generator.

4. The electrified fire fighting vehicle of claim **3**, wherein the motor/generator is a first motor/generator, and wherein the electromechanical device includes a second motor/generator coupled to the first motor/generator.

5. The electrified fire fighting vehicle of claim **4**, wherein the electromechanical device includes a plurality of planetary gear sets positioned between the first motor/generator and the second motor/generator.

6. The electrified fire fighting vehicle of claim **1**, wherein the energy storage system includes:
- a housing positioned between the cab and the body, the housing extending upward from the chassis such that the housing extends above at least a portion of a roof of the cab; and
- a plurality of batteries disposed within the housing, the plurality of batteries stacked vertically along at least a portion of the height of the housing.

7. The electrified fire fighting vehicle of claim **6**, wherein the housing has a depth of 20 inches or less.

8. The electrified fire fighting vehicle of claim **6**, wherein the energy storage system includes a heat exchanger supported by the housing.

9. The electrified fire fighting vehicle of claim **6**, wherein the pump system includes a pump house coupled to the chassis and positioned between the cab and the body, and wherein the housing of the energy storage system is positioned between the cab and the pump house.

10. The electrified fire fighting vehicle of claim **1**, further comprising a clutched accessory drive positioned between the engine and the electromechanical device, the clutched accessory drive including:
- a clutch coupled to the engine; and
- an accessory drive coupled to the clutch and the electromechanical device, the accessory drive including a plurality of accessories.

11. The electrified fire fighting vehicle of claim **1**, wherein the driveline is operable in a first mode where (a) the engine is off and (b) the electromechanical device uses stored energy in the energy storage system to drive the at least one of the front axle or the rear axle, and wherein the driveline is operable in a second mode where (a) the engine provides a mechanical input to the electromechanical device and (b) the electromechanical device uses the mechanical input to drive the at least one of the front axle or the rear axle.

12. The electrified fire fighting vehicle of claim **11**, wherein, during the second mode, the electromechanical device generates electricity based on the mechanical input and uses the electricity to drive the at least one of the front axle or the rear axle.

13. The electrified fire fighting vehicle of claim **12**, wherein, during the second mode, the electromechanical device uses the stored energy in the energy storage system to supplement the electricity generated by the electromechanical device.

14. The electrified fire fighting vehicle of claim **11**, wherein, during the second mode, the electromechanical device operates as a mechanical conduit that transmits the mechanical input received from the engine to the at least one of the front axle or the rear axle.

15. The electrified fire fighting vehicle of claim **11**, further comprising a subsystem coupled to the electromechanical device, wherein the driveline is operable in a third mode where the electromechanical device drives the subsystem, and wherein the subsystem includes at least one of the pump system or an aerial ladder assembly.

16. The electrified fire fighting vehicle of claim **15**, wherein, during the third mode, the electromechanical device drives the subsystem and the at least one of the front axle or the rear axle, simultaneously.

17. An electrified fire fighting vehicle comprising:
- a chassis;
- a cab coupled to the chassis;

a body coupled to the chassis;
a pump system; and
a driveline including:
a front axle coupled to the chassis;
a rear axle coupled to the chassis;
an energy storage system;
an engine coupled to the chassis, the engine including a first interface;
a clutched accessory drive including:
a clutch coupled to the first interface of the engine; and
an accessory drive coupled to the clutch, the accessory drive including a plurality of accessories; and
an electromechanical device coupled to the chassis and the energy storage system, the electromechanical device including (a) a second interface coupled to the accessory drive such that the clutched accessory drive is positioned between the engine and the electromechanical device and (b) a third interface coupled to at least one of the front axle or the rear axle;
wherein the driveline is operable in a first mode where (a) the engine is off, (b) the clutch is disengaged to decouple the engine from the accessory drive and the electromechanical device, and (c) the electromechanical device uses stored energy in the energy storage system to drive (i) the at least one of the front axle or the rear axle via the third interface and (ii) the accessory drive via the second interface; and
wherein the driveline is operable in a second mode where (a) the clutch is engaged, (b) the engine provides a mechanical input to the clutch via the first interface, which thereby drives the accessory drive and the second interface of the electromechanical device, (c) the electromechanical device uses the mechanical input received through the clutched accessory drive to drive the at least one of the front axle or the rear axle, and (d) the electromechanical device does not generate electricity to charge the energy storage system.

18. The electrified fire fighting vehicle of claim **17**, wherein the driveline is a dual drive driveline such that, during any and all modes of operation of the driveline, the electromechanical device does not charge the energy storage system at any time when driven by the engine.

19. The electrified fire fighting vehicle of claim **17**, wherein the electromechanical device includes at least one of a first motor/generator, a second motor/generator, or a plurality of planetary gear sets between the first motor/generator and the second motor/generator.

20. An electrified fire fighting vehicle comprising:
a chassis;
a cab coupled to the chassis;
a body coupled to the chassis;
a pump system; and
a driveline including:
a front axle coupled to the chassis;
a rear axle coupled to the chassis;
an energy storage system;
an engine coupled to the chassis, the engine including a first interface;
a clutched accessory drive including:
a clutch coupled to the first interface of the engine; and
an accessory drive coupled to the clutch, the accessory drive including a plurality of accessories; and
an electromechanical device coupled to the chassis and the energy storage system, the electromechanical device including (a) a second interface coupled to the accessory drive such that the clutched accessory drive is positioned between the engine and the electromechanical device and (b) a third interface coupled to at least one of the front axle or the rear axle;
wherein the driveline is a dual drive driveline such that, during any and all modes of operation of the driveline, the electromechanical device does not charge the energy storage system at any time when driven by the engine.

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